p l a n n i n g

Featuring articles from:

Tom Gibson and G. Alexander Taft ◆ Dennis K. Ruth
Erica Shingara ◆ George R. Hess

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Carolina Planning is a student-run publication of the Department of City and Regional Planning, University of North Carolina at Chapel Hill.

From the Editors:

This season's *Carolina Planning* covers a variety of themes, including issues of sprawl and smart growth, participatory architecture, and management of water resources and natural areas. We begin with a piece by Tom Gibson and G. Alexander Taft on connections between brownfield redevelopment and transportation planning. Including transit nodes as part of brownfield development, the authors argue, can be an important component of smart growth policy.

Next, we hear from Professor D.K. Ruth of the Rural Studio program at Auburn University, Alabama. This innovative program, whose founder was recently recognized with a MacArthur fellowship, teaches architecture students to work with low-income families in designing environmentally sensitive homes in one of the poorest regions of the United States.

The third piece, on defining sprawl, was written by a group of students at North Carolina State University under the guidance of Professor George Hess. The article is a product of a course taught by Hess in the spring of 2001, *Measuring Suburban Sprawl*. In the piece, the authors present different approaches to measuring sprawl, and apply their criteria to mid-Atlantic urbanized regions in measuring the correlation between their indices and the effects of sprawl.

Finally, we hear from Erica Shingara, a 2001 graduate of the University of North Carolina's Department of City and Regional Planning. Shingara spent the spring of 2001 in the Netherlands, conducting comparative research on approaches to water and natural management there and in this country, looking specifically at the Chesapeake Bay. This article is an edited version of her masters project. For a copy of the complete paper, which includes additional figures and analysis of the Netherlands water and natural resources management, please see:

http://www.unc.edu/depts/carplan

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Cover Image:

The Harris House, part of the Auburn University Rural Housing Studio, which provides low-income families with housing assistance.

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Planner's Digest

Making the Brownfield-Transportation Link: Smart Growth Options for States and Metropolitan Areas

Tom Gibson and G. Alexander Taft

A decade ago, passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) marked a turning point in transportation policy. ISTEA gave states and metropolitan areas much-needed flexibility to set their own transportation funding priorities; it also encouraged them to pursue their transportation goals in concert with community and environmental goals. ISTEA and its successor, the Transportation Equity Act for the 21st Century (TEA-21), have opened up opportunities to coordinate transportation planning and community land use planning — which for much of the post-World War II period took place in separate spheres. Some states have run with these new options, creating not only improved transportation efficiency, but also redeveloping brownfields and reaping economic, community, and environmental benefits linked to smart growth.

Brownfields, Transportation, and Smart Growth

Increasingly, communities across the nation are looking to smart growth as a strategic alternative to abandoning existing urban infrastructure – highways, utilities, and other public services – only to rebuild that infrastructure further outside the city. Smart growth emphasizes development in existing communities and encourages reuse of brownfields as a viable way to save tax dollars, preserve open space and farmland, and protect the environment. Smart growth also encourages the availability of a variety of transportation choices to alleviate traffic congestion and enhance transportation efficiency. Smart growth is therefore a natural link between brownfield redevelopment and transportation improvements.

TEA-21's flexibility has been especially helpful to states and metropolitan areas pursuing smart growth projects. Transportation funding under TEA-21 has supported a variety of activities from transit-oriented development to new bicycle and pedestrian facilities. TEA-21 funding has also supported projects linking transportation efficiency, brownfield cleanup, and economic development. Brownfield revitalization projects that could be significantly enhanced by transportation improvements are eligible for TEA-21 funding, as well as transportation projects that encounter obstacles related to brownfields contamination. Eligible transportation projects include highways, roads, and bridges; public transit; rail; pedestrian and bicycle access; and recreational trails.

Smart Growth Synergy — Achieving Several Goals at Once

Because of the multiple benefits, projects founded on brownfield-transportation links are highly appealing to communities and stakeholders, and many are starting to take advantage of these opportunities. Examples include the Atlantic Station project in mid-town Atlanta, where an urban brownfield — the former site of the Atlantic Steel facility — is

being turned into a multi-use development that meets residential, retail, office, and entertainment needs. As with many brownfield redevelopment projects, there is a strong transportation link. The project's viability depends on a new bridge being built across the interstate to serve pedestrians and bicyclists as well as cars and to link the site to existing rail mass transit (for more information, see http://www.epa.gov/projectxl).

Effectively linking brownfield redevelopment, transportation, and smart growth constitutes a triple win, and often results in a synergy that can achieve multiple goals[1]. Because of the combined economic, community, and environmental benefits expected to result, many of these projects attract additional public and private partners, and leverage additional funding. Consider these examples:

- In Lawrence, Massachusetts, transportation funds will pay for a new vehicle bridge and help to clean up a downtown brownfield (a former Oxford Paper Plant); a new park and pedestrian bridge will also be created as part of the overall revitalization project. To complete the revitalization, the city also received funding from EPA's Brownfields Cleanup Revolving Loan Fund Pilot Program, local banks, a neighboring business, the U.S. Department of Housing and Urban Development's Community Development Block Grant funds, and the Massachusetts Land Bank Grant Fund. The city will achieve several important goals: improving transportation access to downtown, supporting economic development, improving the pedestrian environment, and cleaning up environmental contamination.

- Salt Lake City, Utah, will use federal transportation funds toward the purchase, cleanup, and redevelopment of a 17-acre former Union Pacific railyard for use as an intermodal transportation terminal — a key part of the revitalization of the 650-acre downtown Gateway District. A partnership of federal, state, local agencies, organizations, and private firms is undertaking the project, which is also receiving grant funding from EPA's Brownfields Program. The overall plan includes relocating and consolidating existing rail lines, building a light rail system, redesigning Interstate 15, and creating a vibrant, mixed-use, mixed-income community.

Know Your Options

EPA, the Association of Metropolitan Planning Organizations (AMPO), and the Smart Growth Network recently published a report, *Redeveloping Brownfields with Federal Transportation Funds*, to help states and metropolitan areas understand their options under TEA-21. This report illustrates specific TEA-21 programs that can support brownfield reuse and describes the planning process for funding eligible projects.

To obtain a copy of *Redeveloping Brownfields with Federal Transportation Funds*, please call EPA at (202) 260-7154. For general inquiries to AMPO, call (202) 457-0710x19. The report is available online at http://www.smartgrowth.org. Other relevant Web sites include:

http://www.epa.gov/brownfields, http://www.fhwa.dot.gov/tea21/index.htm, and http://www.fra.dot.gov. CP

[1] See *Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation, and Environmental Quality* (EPA 231-R-01-002; Jan. 2001), especially pp. 75 ff. on "Synergies: Combining Techniques." Report is available free of charge by calling (513) 891-6561, or see http://www.epa.gov/smartgrowth.

Tom Gibson *is EPA's Associate Administrator for Policy, Economics, and Innovation.* ***G. Alexander Taft*** *is Executive Director of the Association of Metropolitan Planning Organizations.*

Rural Housing: Reflecting the Spirit of a Culture

The author discusses the Auburn University rural studio program, a program that seeks to help poverty stricken Alabama rural communities tackle housing challenges. Each semester, fifteen to twenty AU architecture students move to Hale County and help families design and construct houses. Examples of student housing projects are presented.

Dennis K. Ruth

In 1993, two Auburn University architecture professors, Dennis Ruth and Samuel Mockbee, established the Auburn University Rural Studio within the university's School of Architecture. The Rural Studio, conceived as a method to improve the living conditions in rural Alabama and to include hands-on experience in an architectural pedagogy, began designing and building homes in the fall of 1993. Professor Samuel Mockbee and Professor Dennis K. Ruth sought funding to begin the studio and, through the years, it has received additional funding which has helped it become what it is today: a vision of a process to make housing and community projects in one of the poorest regions of the nation.

The students who attend the Rural Studio expand their design knowledge through actually building what they have designed. Utilizing the concept of "context-based learning," the Rural Studio asks the student to leave the university environment and take up residency in a region such as Hale County, Alabama. In doing so, the student joins a poverty-stricken region and "shares the sweat" with a housing client who lives far below the poverty level. The goal of this exercise is to refine the student's social conscience and to learn first-hand the necessary social, cultural and technological concepts of designing and building.

The concept of context-based learning has enabled the Rural Studio to be a leader in envisioning a process by which rural housing, with spirit, can be designed, produced, and built. The term *process* is a valuable one here, for the concept of the Rural Studio is not centered in the design of prototypes or the production of housing types to be occupied by a re-located culture. Rather, it envisions a process counter to the mass production of "dumb" boxes where all families and cultures are seen empirically as the same. The Rural Studio is about housing of the "particular." It demonstrates the known axiom that art must inform science and that empirical knowledge must be overlaid with the values and social manifestations of a culture.

Refining our rural communities is a difficult task at best, and the root of this task should be a process of providing shelter for those rural families who have fallen through all the safety nets designed to house the economically disadvantaged. As poet Wendell Berry reminds us, "there is no safety in belonging to the select few, for minority people or anybody else. If we

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Professor ***Dennis Ruth****, together with Professor Samuel Mockbee, established the Auburn University Rural Studio in 1993. Professor Ruth holds an undergraduate degree in Architecture from Auburn University and a Master's of Architecture from Harvard University. He has served as Department Head for the School of Architecture at Auburn and as Dean of the College of Architecture, Design, and Construction. A registered architect with NCARB certification, Professor Ruth presently teaches in the School of Architecture at Auburn University and serves as Director of the Rural Studio. The Rural Studio can be found on the Internet at http://www.ruralstudio.com.*

are looking for insurance against want and oppression, we will find it only in our neighbors' prosperity and goodwill and, beyond that, in the good health of our worldly places, our homelands." Rural America exhibits a genuine appreciation and affection for people and place. Participating in the nobility of things simple and common through the design of places and houses in the rural environment proves to be invigorating. Our rural cultures are collective communities rich in history and the tradition of self-reliance. Rural America values and respects its matriarchs and patriarchs while envisioning prosperity for its children and their children's children. Through necessity, its citizens understand the cycles of weather, the proper orientation of a building with the sun and the shade of a live oak tree. History has taught them that a breeze flowing through a house has the power to exhaust the heat of the day and provide a restful peace in the night. The expectation of clean water from wells and streams has instilled a respect for the disposal of sewage and waste water. In short, our rural communities are simple and actual. A process for providing rural housing should build on this simplicity.

The Rural Studio process asks that providers of rural housing build upon seven primary themes. They are:

- An appreciation and affection for people and place;
- Enlightenment from the simple and the actual;
- An architectural common ground between technology and found objects;
- Recycling does not necessarily mean re-making but can mean reinterpreting;
- There is a nobility in things genuine and not to be stunned by the power of modern technology and economic influence;
- Housing should reflect the spirit of the user, the creativity of the designer, and the hand of the craftsman. Don't be amazed if all three are found in one; and
- One is always a servant to a culturally rich collective community.

The Rural Studio also contends that for rural housing to be significant it must understand the importance of land and dwelling ownership in order to build where people live and where they own. It must understand that the "spirit" of shelter is as basic as shelter itself and understand the existence of a rich cultural tradition in order to capitalize on it. Students should understand the issue of designing for the particular, and "share the sweat" in order to build a team. It teaches participants to never underestimate the sense of family and community and to involve the young. The project seeks to understand the transitory effects of how trailers, prototype housing, and government programs emphasize "housing for the masses," and to always ask "where do the children play?" Students must be aware of the importance of others and what they bring to the process, and strive to "think outside the box," remembering that experimentation generates ideas that work. The Rural Studio seeks to understand the opposite end of affluence and realize that many families fall through the "safety net." Finally, the community must understand that technology is friendly, and they should understand that university students are a tremendous resource of caring, talent, ingenuity and hard work. The Rural Studio is a case study in the appreciation and consideration of these precepts and issues. It is a multifaceted program with an ultimate goal of improving the education of Auburn University's College of Architecture, Design, and Construction students while simultaneously improving the quality of life in one of the poorest regions in the nation.

The studio is located in western Alabama, in remote Hale County. According to the ADECA 1997 Alabama County Data Book, with a per-capita income of $12,292 (only fifty-nine percent of the U.S. per capita income), roughly one-third of this region's residents live below the poverty level. More than a quarter of the population receives food stamps, and the percentage of residents who are unemployed, at 13.1 percent, is more than double the average unemployment rate for the entire state of Alabama.

Each semester, fifteen to twenty second year architecture students leave Auburn University and move to Newbern, Alabama (in Hale County). Students, together with the Hale County Department of Human Resources, find a family in need, ascertain its housing needs, design a house based upon those needs, and begin the foundations of the structure. In subsequent semesters, a different group of students modifies the design while actually constructing the house.

Working from its most vital ideology, teaching students through context-based learning, that is, actually living in and becoming a part of the community and designing and building houses within the community, the Rural Studio has established four main goals, as follows:

- *To give students of the School of Architecture the opportunity to learn the critical skills of planning, designing, and building houses in a concrete, practical, and socially responsible manner.* This goal is achieved through the Rural Studio's hands-on, culturally based curriculum and is exemplified in the projects planned, designed, and built by Rural Studio students. Undergraduate students of architecture conceptualize their projects, leading the processes involved in construction while carrying their projects through to construction.
- *To form leadership qualities in students by instilling the social ethics of professionalism, volunteerism, individual responsibility, and community service.* Rural Studio projects are structured in such a way as to teach students each of these concepts. The act of attending the Rural Studio itself is a voluntary act because, although the students receive fifteen hours of academic credit, participation is not required by the School of Architecture.
- *To help communities, through partnerships with the state and local welfare agencies, provide suitable and dignified housing.* This goal, when realized, facilitates keeping families together, engenders a sense of self-worth and well-being, helps move social security recipients from welfare to work, and provides families with a strong emotional connection to their home. Ultimately, it provides rural families in poverty with a stronger sense of stability.
- *To develop materials, methods, and technologies that will house the rural poor in dignity and mitigate the effects of poverty upon rural living conditions.* Students are encouraged, through curriculum requirements, to research innovative and sustainable materials and construction techniques.

The students have thus far completed one home per year. The completed homes that most clearly demonstrate our principles are the Bryant House (the "Hay Bale" house), the Harris House (the "Butterfly" house), and the Lewis House. Students are now working on the Shannon Sanders-Dutley House, to be a home for a family with six children. Our students have also completed numerous community projects, among which include a warm/dry room for an elderly man to use in lieu of going into nursing care and re-roofing a trailer so that a mother could be re-joined with her children. In conjunction with these houses and community projects, students have built experimental housing pods for their own home at the Rural Studio. These pods showcase experimental methods of construction and community living. The latest example of student housing is a Corrugated Cardboard Bale Student Pod whose principles will be applied in future home design.

The Bryant House

Called the "Hay Bale House" because of walls constructed of hay bales, the Bryant House is home to Alberta and Shepard Bryant and their

two grandchildren. Located in Mason's Bend, the 24-inch-thick walls are stacked hay bales that have been stuccoed over and provide excellent natural, and inexpensive insulation. One wood-burning stove, located in the living room of the house, heats the entire structure, and the house remains cool throughout the summer because of natural ventilation provided by awning windows in the front of the house. In keeping with Southern culture, the house has a large front porch covered with an inexpensive acrylic roof. Because Shepard Bryant is a fisherman, thesis student Scott Stafford built him a smokehouse to the right of the main structure. The smokehouse was built of stone and covered with a roof made of used D.O.T. signs at a total cost of approximately $40.00.

The Harris House

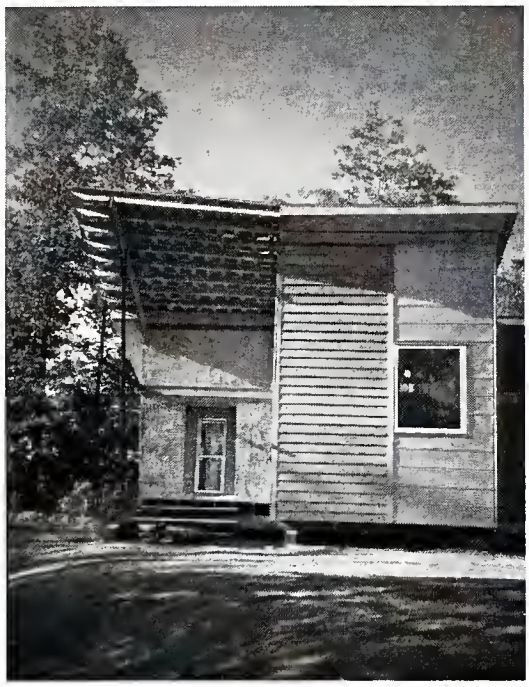
The Harris House, home of Anderson and Ora Lee Harris, was built in the 1996/1997 academic year by second and third year students. Called the "Butterfly House" because of its sharply angled roof structure, the house was a challenge to the students for several reasons. First, because Mrs. Harris is handicapped, the house had to be designed to accommodate a wheelchair. The doorways are wide and easily accessible, with a wheelchair ramp leading to the front door. In the bathroom, fixtures are within easy reach of a wheelchair-bound person. Second, the house is designed to have several energy/cost efficient features. The house had to have ventilation that would allow it to be heated and cooled as inexpensively as possible.

The house is heated by a centrally placed wood-burning stove. Vents, inserted near the roof of the house, may be opened to allow for air circulation in the warmer months or closed in the winter months to trap hot air inside the house. A huge fan at the rear of the house draws air through the central living area. The roof is angled to collect rainwater into a cistern. This gray water system is used to wash clothes and flush toilets. The house has a constructed wetland sewer purification system that provides fertilization to a garden in the backyard and purifies septic system effluent before it reaches the well that holds drinking water. The greatest challenge to the designers was to remain within budget (in this case, under $30,000). To help meet this goal, the roof of the house is clad in tin, with tin and salvaged 105 year-old wood used for the walls.

The Lewis House

Second-year Rural Studio students from 1997 until 1999 designed and built the Lewis House, home to Evelyn Lewis and her four children. The students selected the client with the guidance of the Hale County Department of Human Resources. Headed by a single mother, this family had been living apart for years in the homes of friends and relatives. Lack of resources and affordable housing had forced Evelyn to disperse her children into different homes throughout Hale County. She wanted her family to live under one roof. This desire set her family apart from the numerous needy families the students had met.

In a simple but innovative design, four bedrooms, a living room, a kitchen, and a bath comprise the Lewis House. The students wanted to make the house as functional and economical as possible, with each room serving multiple uses. The family had considerable input into the design, and both mother and children made requests that were included in the completed structure. The bathroom is compartmentalized so that two people can use it at the same time for different purposes. Each of the children's bedrooms has a study space, and each bedroom has its own closet and loft storage space. A central hall connects all rooms in the house. Additional book storage space is built into walls. Windows in each of the bedrooms are aligned with large doors to the hallway, large exterior doors, and openings to take advantage of cool summer breezes. In addition, the hallway includes clear story venting so that the Lewis family may use natural ventilation to cool and heat the house at an extremely low cost.



Clockwise from top left: Lewis House, Bryant House, Harris House

Shannon Sanders-Dutley House

With the assistance of the Hale County Department of Human Resources, 1999-2000 Rural Studio second year students selected the Sanders-Dutley family to be clients for a house. The parents are in their mid-twenties and have six children. The house encompasses fifteen hundred square feet and incorporates three bedrooms, two-and-a-half bathrooms, a kitchen-family room combination, a dining room, and a den. The family gathering spaces open onto a central courtyard, bathed in light at sunrise and sunset. The house is designed to accommodate the many different needs of such a large family, and it attempts to give children and parents adequate private space while creating rooms that foster family interaction. Great consideration was given to daily activities, such as preparation for school, so that the house might ease the

hectic task of rearing six children. The material pallet employs rammed earth for all exterior walls, a steel roof structure, metal studs, and sheet rock on the interior and an abundance of glass and transparent sheets of polycarbonate in clerestory windows.

The rammed earth construction chosen for the Sanders-Dutley house is a building technique in which a cement-soil mixture is compacted into forms to create load-bearing walls that harden into what is essentially man-made, engineered rock. After extensive tests and mock-ups, rammed earth was chosen for the construction method because of its durability, a natural resistance to fire, and its sense of permanence and security. Except for some experimental housing built in the 1930's near Birmingham, Alabama, the Sanders-Dutley House will possibly be the first house in the Southeast to use this method of construction.

Corrugated Cardboard Bale Student Pod

The purpose of this project is to experiment with bales of waste wax-impregnated corrugated clippings in construction. These bales have many properties that make them promising building materials. The thickness of the bales will provide excellent insulation, while the dense packing of the corrugate clippings will create a strong load-bearing structure. Additionally, the thermal mass created will help keep the structure cool in the summer and warm in winter, and the corrugated bales make good material for fast, efficient construction for rural housing.

The first house utilizing this construction material is a student housing "pod." This pod incorporates corrugated bales in both the foundation and walls. Using what is learned through the materials investigations and the "pod" prototype, another structure will be designed and built to test additional ideas.

The architectural students, while applying the Rural Studio process in the building of these houses, have also used basic architectural principles as part of their design process. If one looks closely, one can find an application of nature's materials and found objects available in the rural landscape. The houses apply sustainable cultural principles, simple adaptable technology, and recycling. Visiting the homes today, it is apparent that the houses have fit the social, cultural, and climate context with their planning. Front porches, screen porches, and accessible exterior spaces are well utilized and the houses have proven adaptable over time to each family's particular use. Low energy cost and conservation is reflected in plan layout, the use of natural ventilation, and energy-conserving methods of construction. Reflecting upon the pictorial quality of these homes, one can see the influence of cylindrical hay bales ready to be stored lying in fields, seed barns, and smokehouses, as well as the patina of colors and textures found only in rural America.

These homes act to improve the health and happiness of the residents of Hale County, Alabama. They are, however, only part of the Rural Studio story in rural America. Our students are also engaged in the design and construction of community projects such as children's centers and playgrounds, boys and girls clubs, community pavilions, chapels, baseball and play fields, performance theaters, community centers, and historic preservation. As a result of collaboration between faculty members, students, and community members, many of the goals of the Rural Studio were accomplished. Toward this end, the faculty of the Rural Studio - Andrew Freear, Steve Hoffman, Dick Hudgens, and Samuel Mockbee and Dennis Ruth - have been responsible for the guidance imparted to students in all of the projects and concepts delineated.

To the untrained eye, the measure of success of the Rural Studio is in its built projects; in reality, its success is measured by its effect upon the lives of the faculty, students, families, and communities it touches. It is not only the buildings that make the Rural Studio what it is, but also the education the students receive about architecture and about society. Ultimately, it is about "sharing the sweat" with the community.

Just What is Sprawl, Anyway?

Urban sprawl is a hot-button issue in the U.S. Though the term is widely used to describe the distaste for contemporary American suburban and urban development, a select few group of researchers, academics and practitioners have led the response to the argument against sprawl. This paper seeks to characterize sprawl from the perspective of landscape architecture while focusing on quantitative measurements and definitions of sprawl. At its core it examines the issue of the evolution of urban form through time, and offers options for addressing the debates over the negative or positive ramifications of sprawl.

George R. Hess, Salinda S. Daley, Becky K. Dennison, Robert P. McGuinn, Vanesa Z. Morin, Wade G. Shelton, Sharon R. Lubkin, Kevin M. Potter, Rick E. Savage, Chris M. Snow and Beth M. Wrege

"In the next three or four years Americans will have a chance to decide how decent a place this country will be to live in, and for generations to come. Already huge patches of once green countryside have been turned into vast, smog-filled deserts that are neither city, suburb, nor country, and each day—at a rate of some 3,000 acres a day—more countryside is being bulldozed under. You can't stop progress, they say, yet much more of this kind of progress and we shall have the paradox of prosperity lowering our standard of living. ...The problem is the pattern of growth—or, rather, the lack of one." (Whyte 1958)

Introduction

Sprawl is a hot topic in America. Articles about sprawl have appeared in many magazines and newspapers, including *Time, US News and World Report, The New Yorker, Atlantic Monthly, Sierra, The New York Times,* and *USA Today* (Katz and Bradley 1999; Goldberger 2000; Moberg 2000; Thompson 2000; Tolson 2000; El Nasser and Overberg 2001; Firestone 2001). Search for "urban sprawl" on the World Wide Web and you will be inundated with a combination of research, reports, reviews, and rants. In the academic literature indexed by the *Institute for Scientific Information's Science Citation Database*, the number of titles including the word "sprawl" had increased more than exponentially.

Indeed, sprawl has become the term people use to describe almost anything they do not like about American cities, from traffic jams on endless commercial strips to cookie cutter communities on former farmland. Negative effects attributed to sprawl include economic and racial segregation, crime, poverty, loss of community, increased infrastructure costs, deteriorating air and water quality, loss of farmland and open space, increased traffic congestion, and a general degradation in the quality of human life.

At the same time, a few voices have been questioning the conventional wisdom that sprawl is bad and "Smart Growth" policies are the cure. Among those voices are Peter Gordon and Harry Richardson (1997a), professors in University of Southern California's School of Urban Planning and Development, who contend

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George R. Hess *is an Assistant Professor in North Carolina State University's (NCSU) Forestry Department. The co-authors were all participants in his course,* Measuring Suburban Sprawl, *which was taught during the Spring 2001 semester. This paper is a product of that course.*

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that compact development is not a cure for traffic congestion. Staley (1999) argued that urban growth boundaries do not reduce traffic congestion, that farmland is not imperiled by urban growth, and that sprawl, itself, is not bad.

Yet despite all the purported effects and proposed solutions, a number of researchers noted that the term "sprawl" was rarely quantified until recently (e.g., Burchell et al. 1998; Downs 1998; Galster et al. 2000; Myers and Kitsuse 1999; Malpezzi 1999). There is also a paucity of correlative analysis between measures of sprawl and measures of social, economic, and environmental quality—in part because sprawl itself has not been well defined (Downs 1998; Galster et al 2000).

One of the difficulties in understanding sprawl is that different observers have defined it by a combination of its causes (e.g., zoning and poor planning), characteristics (e.g., low-density development), and effects (e.g., traffic congestion and air pollution). Galster et al. (2000) noted that sprawl has been defined as an aesthetic judgement; as the cause of an externality (e.g., high automobile dependence, job-housing spatial mismatch); as the consequence of some independent variable (e.g., zoning); as a development pattern (e.g., low density, leapfrogging); as a process of development through time; and by example (e.g., with reference to a particular city such as Atlanta or Los Angeles).

Objectives

Ewing (1994), Malpezzi (1999), and Galster et al. (2000) argued convincingly that separating the causes, characteristics, and effects of sprawl is essential to reaching consensus on what sprawl is. We agree and chose to focus our efforts on the spatial characteristics of sprawl. Our primary objective was to identify and quantify characteristics of sprawl on the landscape. What does sprawl look like on the ground? What spatial characteristics should one look for to declare a city sprawled or sprawling?

In this paper, we

- Characterize sprawl from a landscape perspective;
- Present quantitative indices for some of the characteristics of sprawl on the landscape;
- Use these indices to compare sprawl among the U.S. Census-defined urbanized areas in the mid-Atlantic United States; and
- Measure the correlation among our indices and a few purported effects of sprawl.

Landscape Characteristics of Sprawl

The word sprawl has been used to describe the urban environment since the mid 20th century (Table 1). The *Oxford English Dictionary* (2001) defines it as "the straggling expansion of an indeterminate urban or industrial environment into an adjoining countryside; the area of this advancement." Sprawl has been used as an adjective describing the pattern of a city's growth, a verb describing the process of that growth, and as a noun describing an urban landform.

Although the first use we found was by Buttenheim & Cornick (1938), the term became relatively commonplace in the 1940's and 1950's, coincident with two fundamental life changes in the United States—an increase in private automobile use and the expansion of the interstate highway system. While some people were defining and deriding sprawl during the early 1950's, others were advocating the decentralization of American cities as a defense against the possibility of nuclear war (Monson and Monson 1950, 1951; Wigton 1953). However, these advocates of city decentralization favored well-planned, concentrated nodes and were very much against the poorly planned sprawl of central cities (Monson and Monson 1950).

Early uses of the term sprawl suggest that it consumes excessive space in an uncontrolled, disorderly manner leading to loss and poor distribution of open spaces, excessive demand for transportation, and social separation. The

"The folly of allowing further unrestricted expansion and disorderly **sprawling** *of cities into rural areas, turning green fields and forests into dreary city streets and making the countryside inaccessible to the poorer inhabitants of the interior districts, is gaining increasing recognition both in America and Europe." (Buttenheim & Cornick 1938)*

"Among the chief problems facing London, according to the County Plan, were congestion, slums, inadequate and maldistributed open spaces, indeterminate zoning, and **sprawl**, *if one includes the London region." (Rodwin 1945)*

*"The Association poses the alternative of 'self-contained towns' versus '***suburban sprawl***.' It accuses the latter of two basic faults: first, excessive demand for transportation and second, lack of open space for recreation and also expansion." (Blumenfeld 1949)*

" ... in the suburbs that have been growing so rapidly around the great centers the buildings exist, ideally, as free-standing structures in a parklike landscape. Too often the trees and gardens vanish under further pressure of population, yet the **sprawling**, *open individualistic structure, almost anti-social in its dispersal and its random pattern, remains." (Mumford 1953: 223)*

" ... the aimless **sprawl of suburbia** *is destroying a precious asset (open land)." (Haskell 1958)*

*"Great size has another feature that isn't quite so beneficent. With very great population size comes very great area (as well as high density); and, with the increasing use of the automobile, we get '***sprawl***,' all of which leads to intra-area spatial patterns characterized by very considerable social separation." (Thompson 1966)*

Table 1. *Some early uses of the word "sprawl" to describe urban growth patterns.*

essential elements of these early definitions have remained relatively unchanged through time. In her report, *Revisiting Sprawl: Lessons From the Past*, Burgess (1998:1) defined sprawl as "... expanding physical development, at decreasing densities, in metropolitan regions, where the spatial growth exceeds population growth." Lee and Tian (1998) suggested that urban sprawl leads to inefficient land-use, leapfrogging, and low-density development of the urban fringe. The Sierra Club (1998) defined sprawl as "low-density development beyond the edge of service and employment, which separates where people live from where they shop, work, recreate, and educate—thus requiring cars to move between zones." Brueckner (2000) defined urban sprawl as excessive spatial growth of cities.

After a comprehensive literature review (Hess 2001), we noted a number of common characteristics among sprawl definitions (Table 2). Ewing (1994, 1997), Malpezzi (1999), and Galster et al. (2000) provided valuable reviews of sprawl definitions. The characteristics associated most frequently with sprawl were low-density development, strip development, scattered development away from the central city, leapfrog development, and separation of land uses. Density is by far the most common measure, followed by comparisons between the rate at which land is urbanized and the rate of population growth (e.g., land was urbanized at three times the rate of population growth). Ewing (1997) argued that poor accessibility—difficulty moving among widely separated land uses—and a lack of functional, public open spaces are the primary hallmarks of sprawl.

There seems to be general agreement that sprawl is a matter of degree. For example, it is difficult to say at what density a city becomes sprawled, but relatively easy to say that one city is less dense than another and therefore more sprawling in that aspect.

Some researchers consider time to be a critical component in the measurement of sprawl (US EPA 2000; Ewing 1994; Harvey and Clark 1965). Harvey and Clark (1965) noted that sprawl cannot be measured and described at one

Characteristic (our measures)*	Description	Selected Citations
High / inefficient land consumption; low population density (LAND, LAND9080, FCLAND)	Low population density; high levels of urbanized land per person; rate of land urbanization greater than rate of population growth, especially in fringe areas.	Black 1996; Downs 1998, Freeman 2001; Galster et al. 2000; Harvey and Clark 1965; STPP 2000; Montaigne 2000
Fringe Development (FCAREA1990, LAND9080, FCAREA9080)	Development away from city center; rapid development of open spaces on city boundary.	Besl 2000; Downs 1998; Galster et al. 2000; Katz and Bradley 1999
Lack of connectivity (DRIVE)	Arterial street systems; lack of grid; lots of dead ends.	Duany and Plater-Zyberk 1998; NRDC 1996
Leapfrogging; scattered development (DRIVE)	Development that skips over empty parcels.	Clawson 1962; Mills 1981; Downs 1998; Gordon and Richardson 1997b, Yeh and Li 2001
Separation of uses (DRIVE)	Different land uses (employment, retail, residential) are far apart; residential development beyond edge of employment and retail services; lack of residential development in city center.	Brown et al. 1998; Downs 1998; Duany and Plater-Zyberk 1998; Ewing 1994,1997; Galster et al. 2000
Lack of functional open space	Lack of open space that performs a useful public function; ill-defined residual space.	Anonymous 1999; Ewing 1997, 1994
Aesthetics and architecture	You know it when you see it. Big-box retail; strip malls; no sidewalks; excessively wide roads. Large, disjointed buildings set back from street, highly articulated, rotated on lots.	Duany and Plater-Zyberk 1998; Gore 1998; Koffman 1999; Kunstler 1996; NRDC 1996

*Our measures are defined fully in Table 3.

Table 2. *Spatial characteristics of sprawl found in the literature.*

moment in time, because sprawl is a form of growth. They argued that it is the trend in population density, rather than current population density, that determines whether a city is sprawling or not. A city becoming less densely populated through time is said to be sprawling, even if it is currently quite densely populated in comparison to other cities.

Approaches to Measuring Sprawl

Several authors have decried the lack of quantitative approaches to defining sprawl, yet few have developed comprehensive ways to measure sprawl. The Sierra Club (1998) ranked U.S. Census-defined urbanized areas by considering trends in population and land area growth, traffic congestion and open space loss indicators. They also accounted for loss of important wildlife habitat and historical sites. In *USA Today*, El Nasser and Overberg (2001) ranked all of the US Census-defined Metropolitan Statistical Areas by considering trends in the proportion of the population in the Metropolitan Statistical Areas

living in urbanized areas.

Malpezzi (1999) and Galster et al. (2000) have done the most cogent work to date, focusing primarily on measuring the spatial characteristics of urban landscapes. Malpezzi (1999) examined several measures of the spatial distribution of population density among census tracts of all U.S. Metropolitan Statistical Areas. He compared overall density; maximum and minimum tract density; density of the median, tenth, and ninetieth percentile population-weighted tracts; coefficient of variation of the tract densities; Theil's information measure; the Gini coefficient; parameters of the densities' fit to a spatial exponential or other function; the r-square statistics thereof; and the average distance of each person to the central business district. He found strong correlations among the percentile measures, and weaker correlations among the other measures. Malpezzi also examined the correlation between spatial measures and commuting measures, and found (with strong correlation) that denser areas have shorter commutes, and that areas with high median home prices also have shorter commutes.

Galster et al. (2000) examined six different measures of residential development:

1) Density, the average number of residential units per square mile;
2) Concentration, the degree to which development is located within a relatively few square miles of the urbanized area;
3) Compactness, the degree to which development has been clustered;
4) Centrality, the degree to which development is located close to the central business district;
5) Nuclearity, the extent to which an urbanized area is characterized by a single center of development; and
6) Proximity of land uses, the degree to which different land uses are close to one another.

They applied these measures to thirteen large U.S. cities and ranked them from least to most sprawled according to each of the above six measures. They further summed all of the ranks for a city to provide an overall measure of sprawl for each city. Galster et al. (2000) also proposed two other measures for future development: *continuity*, the degree to which land has been developed in an unbroken fashion; and *diversity of land uses*, the degree to which different land uses exist within portions of the urbanized area.

Yeh and Li (1998, 2001) used a geographical information system (GIS) analysis of remotely sensed data to measure and monitor the degree of urban sprawl for cities and towns in China. They characterized sprawl as scattered new development on isolated tracts separated from other areas by vacant land. To quantify the degree of scattering they calculated Shannon's entropy, a statistical measurement of dispersion based on the relative numbers of an item (the amount of new development, in this case) in each of several compartments (concentric rings around a city, in this case). Cities and towns with higher entropy values were characterized as more sprawled because they exhibited more dispersed development—the new development was spread evenly among the compartments. Yeh and Li also used entropy to measure dispersal of development along major roads and highways. Although Yeh and Li did not do so, a series of entropy measures through time can be used to determine changes in the degree to which a city's development is dispersed or compact.

Our Measures of Sprawl

We defined seven measures that relate directly to several spatial characteristics of sprawl (Table 3). We restricted our efforts to measures that could be calculated using data readily available in a standardized format for cities nationwide. We focused our efforts on U.S. Census-defined urbanized areas, because they are defined consistently throughout the United States. We used 1990 United States Census and related Federal Highway Administration data, because they are the most recent data available for urbanized areas in the United States. Most of the measures reflect land consumption, differences between land consumption in the center and fringe of the urbanized area, and changes in land consumption rates through time.

Measure	Description / Rationale (Data Source)	Formula
	Land Consumption	
AREA	Area of urban area (square miles) in 1990. Larger urban areas consume more land, and are considered more sprawling. (US Census Bureau)	UA* Area
LAND	Urbanized land per capita in 1990. Size of urban area / population (acres per 1,000 people). A more sprawling city uses more land per person. (US Census Bureau)	$\frac{\text{UA Area (acres)}}{\text{UA Population (1,000s)}}$
	Population Concentration	
FCAREA	Fringe-to-center area ratio in 1990. Ratio of fringe area to area of city center. Sprawled cities are said to have more development away from their city centers. (US Census Bureau)	$\frac{\text{Area of UA Fringe}}{\text{Area of UA Center}}$
FCLAND	Fringe-to-center land per capita ratio in 1990. Ratio of land used per capita in the fringe to land used per capita in the city center. Sprawled cities are often said to have much higher land consumption per capita in the fringe than in the center. (US Census Bureau)	$\frac{\text{Fringe Area / Fringe Pop}}{\text{Center Area / Center Pop}}$
	Separation of Land Uses/Accessibility	
DRIVE	Daily Vehicle Mileage per Capita in 1993. This measure reflects the average daily mileage per capita relative to cities of the same population density. >1 means more driving than average for cities of same density <1 means less driving than average for cities of same density We used this index as a surrogate for measuring several spatial characteristics of sprawl. Separation of land use, lack of connectivity, and poor accessibility are spatial characteristics of sprawl that result in increased driving and higher values of this index. (US Federal Highway Administration)	$\frac{\text{Observed Daily Mileage}}{\text{Expected Daily Mileage}}$ (See text for details)
	Temporal Development Patterns	
FCAREA9080	Ratio of fringe-to-center area ratio in 1990 to 1980 value. Cities are more sprawling when the size of their fringe areas increases faster than the size of their centers (i.e., FCAREA9080 > 1). (US Census Bureau)	$\frac{\text{FCAREA (1990)}}{\text{FCAREA (1980)}}$
LAND9080	Ratio of urbanized land per capita in 1990 to 1980 value. Cities are sprawling when their rate of land use per capita is increasing (i.e., LAND9080 > 1). (US Census Bureau)	$\frac{\text{LAND (1990)}}{\text{LAND (1980)}}$

*UA = US Census-defined urbanized area

Table 3. *Quantitative measures of sprawl that we calculated. For all measures, higher values indicate more sprawl.*

The U.S. Census Bureau defines an urbanized area as one or more central places and the adjacent densely settled urban fringe that together contain a minimum of 50,000 persons (US-DC 1994). The definition has been used since 1950 to provide a better separation of urban and rural territory, population, and housing in the vicinity of places with relatively large populations. The definition has changed somewhat through time, but has been relatively consistent since 1970. The urban fringe generally consists of contiguous territory having a density of least 1,000 persons per square mile. The urban fringe also includes outlying territory, if it is connected to the core of the contiguous area by road and is within 1.5 road miles of that core, or within five road miles of the core but separated by water or other undevelopable territory. Other territory with a population density of fewer than 1,000 people per square mile is included in the urban fringe if it eliminates an enclave or closes an indentation in the boundary of the urbanized area.

Our early analyses showed that the size (square miles) and population (number of people) of urbanized areas were correlated at the total (r=0.97), fringe (r=0.99), and center (r=0.70) scales. Because we were focusing on landscape characteristics, we chose to work with area measures instead of population measures. Similarly, we used measures of land consumption—the amount of land used per person—which is the inverse of population density. One can also measure land used per housing unit; however, housing unit density and population density were completely correlated in our study area (r=1.0).

Separation of land uses and accessibility are important and related dimensions of sprawl that are difficult to measure directly. The term "accessibility" is used in the sprawl literature to represent the ease of movement among different land uses, especially home, work, and services (e.g., Koenig 1980). Accessibility is influenced by the degree to which these land uses are separated on the landscape. Personal transportation surveys (e.g., US-FHA 2001) are the best approach to measuring accessibility, because they provide information about what people are doing, where they are going, and how they are getting there. Unfortunately, they are costly to implement and available for only a limited number of Metropolitan Statistical Areas.

We used average daily vehicle miles traveled per person as a surrogate measure for degree of accessibility and separation of land uses. Daily vehicle miles traveled per person are reported by Census-defined urbanized area in the annual U.S. Department of Transportation *Highway Statistics* publication. The data are based on a statistical analysis of traffic counts using the Highway Performance Monitoring System (Office of Highway Policy Information 2000). We used data from the 1993 Highway Statistics (Office of Highway Information Management 1994), because these were the first developed using 1990 urbanized area boundaries.

One must be careful when comparing cities of different densities, because vehicle miles traveled decreases with increasing population density (e.g., Ewing 1997). Therefore, we developed a "DRIVE" index that accounts for population density. By fitting a curve to daily vehicle miles traveled per person as a function of population density, we were able to calculate the expected daily vehicle miles traveled (DVMT) based on the density of a city. Our index was obtained by calculating

$$\text{DRIVE} = \frac{\text{Observed DVMT / person}}{\text{Expected DVMT/person, based on urbanized area density}}$$

Because the index is normalized by urbanized area density, it is only comparing cities of like density. We argue that higher values of this index are related to relatively high automobile use that results from greater separation of land uses and poorer accessibility.

Applying Our Measures of Sprawl to the Mid-Atlantic Urbanized Areas

We applied our seven measures (Table 3) to the forty-nine cities in the seven mid-Atlantic states (Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia) that (1) were considered urbanized areas in both 1980 and 1990, and (2) for which Federal

Highway Administration data were available.

We ranked the cities according to the degree of sprawl for each characteristic (Table 4). We also evaluated the linear correlation among the seven measures, and found that none of the measures were highly correlated (Table 5). The highest magnitude of any correlation (0.48) was between the fringe-to-center area and land consumption ratios; most correlations were much weaker. This lack of strong correlation implies that each index is measuring something different.

Agglomerative Cluster and Principal Components Analyses

An agglomerative cluster analysis was used to identify groups of cities with similar characteristics. Clustering is a mathematical technique that groups entities with similar attributes by measuring the distance between them in multidimensional space. At each step in an agglomerative cluster analysis, the two entities or groups of entities that are most similar to one another are grouped into a single cluster. A number of approaches can be taken to measure the distance between clusters. We used Ward's Method, which measures the variance between clusters at each step and joins the clusters with the minimum variance. The cluster analyses were performed using JMP (SAS 2001).

We also performed a principal components analysis on our measures. Principal components analysis is a numerical method used to analyze multivariate data (Legendre and Legendre 1998). It is an ordination technique that is used to summarize trends and patterns among samples (urbanized areas, in our case), given a number of characteristics for each sample. The output of a principal components analysis is a score that combines the characteristics that explain most of the variance among samples. The principal components analysis was performed using PC-ORD (MjM Software Design 2000).

Both cluster and principal component analyses were performed on Z-transformed indices, or Z-scores. A Z-score is the number of standard deviations an observation is from the mean of the distribution. We used Z-scores instead of the raw index values, because the index values were of very different magnitudes. Cluster and principal component analysis are sensitive to large differences in magnitudes and will return spurious results if data are not transformed.

We used cluster and principal components analyses to group cities with similar characteristics of land consumption (LAND), fringe-to-center land consumption ratio (FCLAND), and daily vehicle miles traveled per person. We used the observed daily vehicle miles traveled per person rather than our density-adjusted DRIVE index, because density was incorporated into the analyses (through LAND) and both methods therefore account for differences in density.

According to our cluster analysis, most of the difference between groups of cities was explained by overall land consumption (LAND), followed by the fringe-to-center land consumption ratios (FCLAND), followed by daily vehicle miles traveled per person. Principal components analysis of the same variables yielded similar results (Table 4). The first principal axis captured 57 percent of the variance in the data, and was most closely associated with land consumption (LAND) and daily vehicle miles traveled per person. The second axis captured an additional 24 percent of the variance and was most closely associated with the fringe-to-center land consumption ratio (FCLAND).

The larger, older cities all had relatively low levels of land consumption and relatively low levels of daily driving per capita. Among cities with low levels of land consumption, daily driving per capita was relatively low, regardless of the

Table 4 (right). *Sprawl rankings of 49 urbanized areas in the mid-Atlantic states from most sprawled (1) to least sprawled (49). The first column lists the urbanized areas from most to least sprawling as ranked by the first principal axis of a principal components analysis of overall land consumption (LAND), fringe-to-center land consumption ratio (FCLAND), and observed daily vehicle miles traveled. The remaining columns show the rank of each urbanized area for each of our seven sprawl indices, from the most sprawled (1) to the least sprawled (49).*

City (principal axis 1)	AREA	LAND	FCAREA	FC LAND	DRIVE	LAND 9080	FCAREA 9080
1. Asheville NC	23	7	32	31	4	34	30
2. Hickory NC	32	5	24	42	5	23	45
3. Vineland-Millville NJ	15	1	48	49	44	48	35
4. Kingsport VA	20	2	27	43	23	22	44
5. Lynchburg VA	19	3	39	29	20	24	6
6. Bristol TN/VA	38	4	44	24	22	37	33
7. High Point NC	30	14	41	41	13	20	38
8. Burlington NC	39	17	34	38	1	31	24
9. Gastonia NC	27	13	30	37	11	27	36
10. Raleigh NC	11	23	40	32	3	11	10
11. Greensboro NC	25	32	47	22	2	25	41
12. Winston-Salem NC	16	20	42	26	10	41	31
13. Danville VA	42	8	49	19	24	3	49
14. Wilmington NC	29	6	31	27	32	44	39
15. Goldsboro NC	40	11	35	15	38	46	46
16. Norfolk-Virginia Beach VA	3	9	43	13	37	2	48
17. Durham NC	18	30	46	44	16	26	47
18. Charleston WV	21	21	26	46	12	4	4
19. Atlantic City NJ	17	16	13	40	14	8	29
20. Charlotte NC	8	27	45	23	19	47	18
21. Roanoke VA	26	31	38	45	17	42	20
22. Petersburg VA	33	19	29	47	36	19	2
23. Richmond VA	7	29	19	34	7	40	9
24. Fayettville NC	14	24	25	48	39	43	32
25. Hagerstown MD	44	22	21	14	28	36	19
26. Huntington-Ashland WV/KY	24	25	23	33	29	7	8
27. Annapolis MD	37	18	11	5	31	5	11
28. Jacksonville NC	31	12	16	30	48	49	40
29. Parkersburg WV	48	36	37	39	40	6	7
30. Allentown PA	13	42	22	28	30	35	15
31. Charlottesville VA	47	39	33	25	33	14	5
32. Altoona PA	46	40	28	8	41	21	25
33. Scranton-Wilkes-Barre PA	9	28	14	20	42	30	22
34. Harrisburg PA	12	26	2	16	8	28	34
35. Sharon PA	43	10	5	3	49	1	1
36. Erie PA	34	41	36	35	45	9	27
37. Johnstown PA	45	34	17	17	43	15	26
38. Baltimore MD	6	43	12	10	18	18	17
39. Wilmington DE	10	37	7	36	15	39	43
40. Reading PA	35	46	18	11	34	33	13
41. State College PA	49	45	20	1	47	10	3
42. Trenton NJ	22	44	4	4	9	38	23
43. York PA	36	38	8	9	21	32	14
44. Monessen PA	41	15	1	21	46	13	12
45. Washington DC	4	47	9	18	6	45	37
46. Pittsburgh PA	5	33	3	12	35	12	28
47. Lancaster PA	28	35	6	7	27	29	16
48. Philadephia PA	2	48	10	6	25	17	21
49. New York NY	1	49	15	2	26	16	42

	AREA	LAND	FC LAND	FC AREA	LAND 9080	FCAREA 9080	DRIVE
AREA	1						
LAND	(0.31)	1					
FCLAND	0.38	(0.44)	1				
FCAREA	0.14	(0.32)	0.48	1			
LAND9080	0.03	0.07	0.31	0.13	1		
FCAREA9080	(0.2)	(0.17)	0.27	0.22	0.43	1	
DRIVE	0.02	(0.04)	(0.26)	(0.12)	(0.27)	(0.27)	1
PC 1	(0.30)	0.79	(0.60)	(0.68)	(0.11)	(0.30)	(0.41)

Table 5. *Correlations among sprawl measures. Sprawl measures are defined in Table 3; PC1 is the score of the first principal components axis; negative numbers are shown in parentheses.*

fringe-to-center consumption ratio. No cities had both high levels of land consumption and a high ratio of fringe-to-center land consumption. In essence, both the core and fringe of cities with high rates of land consumption were developed at similar densities. Cities with high land consumption levels were further differentiated by the relative amounts of driving per capita. Many of the cities with high levels of daily driving per capita have recently experienced periods of high growth and economic prosperity.

Correlates of Sprawl: Forest Fragmentation

Background

Widespread concern about environmental degradation as a result of regional development patterns emerged in the 1960's and 1970's (Burgess 1998). Land transformation has been cited as the major force driving losses in biological diversity (e.g., Vitousek et al. 1997). Habitat fragmentation, in particular, has been documented as having negative effects on biodiversity by increasing "edge effects," and isolating animal populations at a variety of spatial scales (Lovejoy et al. 1986, Laurance et al. 1997). Though rarely mentioned directly, issues related to fragmentation, such as loss of and limited access to open space, are often cited as negative effects of "leapfrogging" development (Downs 1998; Ewing 1994, 1997). Sprawling development is said to result in small, isolated patches of habitat surrounded by land in residential, commercial, or industrial uses. In the mid-Atlantic region, concern about habitat fragmentation is focused on forested habitat, largely because forest is the climax vegetative community in the region.

Methods

We tested the hypothesis that the degree of forest fragmentation in and around an urbanized area is directly related to the degree of sprawl. We used forest fragmentation maps developed by Riitters, et al. (2000) from Multi-Resolution Land Characteristics (MRLC) land-cover maps derived from 1992 Landsat Thematic Mapper (TM) data, at 30 meter by 30 meter resolution. Riitters et al. (2000) assigned one of six fragmentation categories to each forest pixel based on the land cover in three fixed-area windows surrounding the pixel (9x9, 27x27, 81x81). Fragmentation categories are: interior, perforated, undetermined, transitional, edge, and patch. We used data from the smallest scale (highest resolution) window (9x9) for our analysis.

We considered all but the forest interior category to be fragmented and calculated the proportion of all forest pixels that were interior forest in each urbanized area. Because sprawl is said to affect habitat near urbanized areas, we also calculated the percent interior forest in a five-kilometer buffer around the urbanized areas.

Findings

Neither the proportion of interior forest within the urbanized area nor the proportion in

the five kilometer region around the urbanized area were correlated strongly with any of our measures of sprawl (Table 6).

Socioeconomic Measures

Background

Because sprawl has been blamed for a variety of social ills, we set out to determine if any of our measures were correlated with easily measured socioeconomic indicators. In *Sprawl City: Race, Politics, and Planning in Atlanta*, Bullard et al. (2000) presented arguments that typify the discussion of socioeconomic issues related to sprawl. Bullard et al. (2000) theorized that government policy, including housing, education, and transportation policies, have subsidized separate but unequal economic development, segregated neighborhoods, and affected the spatial layout of central cities and suburbs. They offer an environmental justice framework with which to investigate the social effects of sprawl on minority and low-income individuals. Environmental justice encompasses environmental racism—discrimination that targets people of color and certain socioeconomic backgrounds and excludes them from planning decisions—and environmental inequity, which denies ethnic and low-income individuals access to employment centers.

Methods and Findings

We selected a number of socioeconomic attributes available from 1990 US Census data and examined their correlation with our measures of sprawl (Table 7). None of the attributes were correlated strongly with our sprawl measures (Table 6). We examined scatterplots of the moderately correlated (>0.4) pairs and found that they were dominated by one or two outlying values, making any generalizations suspect. Although the relationship is weak (r=0.43), our index of land use separation and accessibility (DRIVE) does appear to increase as the median age of housing (MEDAGE) decreases. The implication is that urbanized areas with new housing stock have a larger separation of land uses and poorer accessibility, resulting in more driving.

Future Work

Our sample size was relatively small in terms of performing cluster and principal components analyses, and New York was an outlier in several respects (e.g., area, density). Applying our

	AREA	LAND	FC LAND	FC AREA	LAND 9080	FCAREA 9080	DRIVE	PC 1
Forest Fragmentation								
Inside UA*	0.17	0.34	(0.07)	(0.13)	(0.19)	(0.05)	(0.36)	(0.04)
UA Buffer**	0.01	(0.04)	0.02	(0.22)	(0.23)	0.06	(0.28)	(0.05)
Socioeconomic Measures								
HS%	(0.12)	0.09	(0.04)	0.33	0.10	0.06	(0.42)	(0.22)
GRAD%	0.20	(0.47)	0.27	0.06	0.00	0.13	0.20	(0.27)
PCINCOME	0.38	(0.45)	0.25	0.13	(0.12)	(0.06)	0.35	(0.25)
POVERTY	(0.28)	0.20	0.01	(0.29)	0.30	0.25	(0.43)	(0.12)
MEDAGE	0.03	(0.26)	0.30	0.38	0.20	0.21	(0.43)	(0.49)
MEDVALUE	0.56	(0.40)	0.34	0.22	(0.16)	(0.12)	0.28	(0.31)

* UA = US Census-defined urbanized area

** Within a 5-kilometer buffer around the urbanized area

Table 6. *Correlations between sprawl measures and measures of potential environmental and socioeconomic correlates. Sprawl measures and definitions are provided in Table 3; PC 1 is the score of the first principal components axis; fragmentation variables are described in the text; socioeconomic variables are described in Table 7. Negative numbers are shown in parentheses*

Variable	*Description / Rationale*
Educational Attainment	
HS% GRAD%	Percent of people age 25 years and older for whom high school or graduate school is the highest level of education. Higher levels of education generally translate to higher income and increased ability to satisfy preference for low-density housing. Expect higher level of educational attainment to be correlated positively with sprawl. (Bullard et al. 2000)
Income	
PCINCOME	Per capita income for people age 5 years and older. In surveys, upper income individuals expressed a desire for low-density housing and the flexibility to be mobile. Expect sprawling cities to have a higher per-capita income. (Bullard et al. 2000)
POVERTY%	Percent of individuals age 5 years and older who fall below the 1989 poverty line. Sprawl leaves a decaying inner city with high rates of poverty. Expect sprawling cities to have higher poverty levels. (Bullard et al. 2000)
Housing	
MEDAGE	Median age of housing stock in 1989. During the 1950s-1970s, the influx of tract developments created affordable, low-density housing. Expect cities with newer homes to be more sprawling. (Dear and Elliot 2001)
MEDVALUE	Median home value in 1989. Real estate markets have a direct influence on cost and availability of housing in urbanized areas. High costs in the city center drive people into the fringe. Expect cities with higher median housing values to be more sprawling. (Dear and Elliot 2001)

Table 7. *Description of socioeconomic variables we correlated against our measures of sprawl.*

measures to all the urbanized areas in the US, increasing our sample size from 49 to nearly 400, might reveal additional trends.

Conceptually, we agree with Ewing (1994) that accessibility and lack of functional open space are key characteristics of sprawl. We do not agree with his assessment of the ease with which these characteristics can be measured. The daily vehicle miles data we used are an imperfect measure of accessibility, because they are aggregated data that provide no information about what individual drivers are doing or where they are going. Personal transportation surveys (e.g., US-FHA 2001) are a better approach to measuring accessibility, because they provide information about where people are going, and how they are getting there. Unfortunately, they are costly to implement and available for only a limited number of Metropolitan Statistical Areas. Further exploration of accessibility measures that can be calculated easily for all urbanized areas would be an important contribution to the sprawl literature.

We did not develop any measures of functional, public open space. These data are difficult to develop on a national scale, because no agency collects them consistently. It is also unclear how privately owned, undeveloped lands would be accounted for in a measure of open space. While it is possible to delineate undeveloped lands using aerial photography or satellite imagery, determining if they are functioning as desired (e.g., as wildlife habitat) is a more difficult task. Data on public parks might be available in a fairly consistent form nationally, and might provide an additional measure of sprawl.

Shannon's entropy measure of spatial dispersion merits further investigation (Yeh and Li 2001). In a small pilot study, we analyzed census population data at the block level using a geographic information system to calculate the

degree of entropy for 14 North Carolina urbanized areas. Entropy was calculated using four concentric rings of equal area around an urbanized area's center of population mass. The largest ring had a radius equal to the longest span from the center of population to the urbanized area boundary. The urbanized areas were differentiated by entropy, which was not well correlated with any of our other sprawl measures. A combination of entropy and population moments (e.g., Malpezzi 1999) might allow one to refine the spatial resolution of our density measures.

Conclusion

The essential issue being addressed in the sprawl debate is the evolution of urban form through time. Cities grow, with or without planning, and develop landscape characteristics that persist through time and determine how they will function. The word "sprawl" is being used to describe a contemporary urban growth form, as well as the effects of that form. Galster et al. (2000) suggested that sprawl can have a number of dimensions, and that cities might sprawl differently along these dimensions. Our analyses support this notion. We calculated seven sprawl measures and found little correlation among them, indicating that they each measure a different dimension of sprawl. Further, few of our measures correlated well with Galster et al.'s (2000); nor did they correlate with the measures presented in *USA Today* (El Nasser and Overberg 2001).

With so many possible measures—none correlated strongly with the measures of environmental and socioeconomic issues we examined—we found ourselves wondering, "Just what is sprawl, anyway?" Clearly, sprawl is multi-faceted. How sprawl is defined may indeed be in the eye of the beholder, because different dimensions of sprawl may be important for different environmental and socioeconomic issues. Conceptual models relating the characteristics of sprawl to purported effects of sprawl are needed to select appropriate sprawl measures. For example, people concerned about loss of wildlife habitat and farmland may be most interested in land consumption and the rate at which it is increasing (LAND and LAND9080). Those concerned with air pollution may be more interested in the sheer size of an urbanized area (AREA) and the separation of land uses, as reflected by our DRIVE measure. If traffic congestion is the major concern, accessibility and separation of land uses are likely to be of paramount concern (DRIVE). In this case, density is only important insofar as it contributes to separation of land uses. People who agree with Harvey and Clark (1965) that sprawl is best measured by trends in density will be most interested in our temporal indices (LAND9080 and FCAREA9080).

Rather than attempting to develop composite indices of sprawl (e.g., Sierra Club 1998; El Nasser and Overberg 2001), it may be more useful to examine urban development patterns along a number of gradients. For example, our cluster and principal components analyses demonstrated that cities can be grouped based on a number of different measures. These analyses reflected the ability of spatial configuration to differentiate groups of cities, even with the relatively coarse data we used. Overall land consumption rates and the relative densities at which the urban center and fringe are populated explained much of the differences among groups of cities. Daily vehicle miles traveled per person differentiated patterns at finer scales. Although we found no strong correlation between our individual measures of sprawl and our measures of environmental and socioeconomic condition, further examination of these issues is warranted with respect to the clusters of cities we identified.

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Planning to Protect Water and Natural Areas

Worldwide, there is a growing recognition for the need to balance development with watershed protection and water basin management. Any sustainable effort must recognize the interdependence of land use, spatial development, natural areas and water resources. The Chesapeake Bay Program provides an example of comprehensive, integrated and innovative water basin management. Although not flawless, it can serve as a model for the development of other regional watershed protection and management programs in the United States and around the world.

Erica Shingara

INTRODUCTION

Overview of water and natural area management

Urban sprawl, fragmented natural areas, and polluted air, soil, and water challenge urban and regional planners throughout the world. Water and nature management is exceedingly difficult because these resources have multiple uses, are impacted by numerous pollution sources, and intersect jurisdictional boundaries. The traditional environmental planning approach to these problems is based on the separation of urban, rural, and environmental functions and tends to primarily focus on the protection of natural areas. However, this is not a sustainable method of planning because "islands of nature will not survive in a sea of destructive practices in agriculture and urban development" (Tjallingii, 1996, p. 18). Therefore, planning must seek to achieve a better balance between ecosystem and watershed integrity and the provision of human, social, and economic services. In order to accomplish this, planning must recognize that problems with water and natural areas (e.g., pollution, the abundance or shortage of water, water quality, impacts of sprawl and poor habitat quality and quantity) are interrelated.

Therefore, in order to balance the need for growth while promoting watershed protection, water basin management must recognize the interdependence of land use, spatial development, natural areas and water resources. For this reason, a holistic approach to planning is needed that integrates ecological, spatial, environmental, economic and water management principles into planning in order to minimize the adverse impacts of development and land use. There are numerous strategies for non-point source abatement, mitigation of water quality impacts, and the protection of natural areas (Lundqvist, Lohm, and M. Falkenmark, 1985):

- *Regulatory approaches*—nutrient caps, pollution permits, cross compliance, and river basin organizations.
- *Economic instruments*—land evaluation, taxes, fees, subsidies, cost recovery, economic incentives, investment policies, and permit trading.
- *Analytical tools*—research, predictive modeling, monitoring, and project evaluation.
- *Management plans*—that assess the social, educational, legal, administrative, technical, and financial factors to create a realistic plan for the optimal integrated management of land and water

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***Erica Shingara**, a graduate of the University of North Carolina's Department of City and Regional Planning, was awarded the prize for best masters project of the class of 2001. The full project compares the Chesapeake Bay Program with similar water and natural area management strategies used in the Netherlands. This article is an excerpt of her paper, adapted for publishing by the editors of* Carolina Planning.

resources (e.g., river basin planning and tributary strategies).

- *Spatial and land management techniques*—critical area programs, transfer of development rights (TDRs) from sensitive areas to areas identified for growth, riparian stream buffer restoration programs, transportation planning to decrease emissions and atmospheric deposition, land acquisition programs, urban growth boundaries, and subdivision and zoning regulations.
- *Best management practices (BMPs)*—to decrease runoff from agriculture (e.g., nutrient balance, low-input farming, economic incentives, cost share programs, and education), urban areas (e.g., separated sewage and storm water collection systems and designs that decrease permeable services and filter pollutants), and construction areas (e.g., erosion control techniques).
- *Education and training*—to achieve coordination of land and water management and conservation.

Combinations of these strategies are utilized in programs throughout the world to promote integrated land, water, and environmental conservation and management. Cases illustrating the complexity of watershed management and the use of innovative management strategies are evident in Europe and the United States, both of which face growing watershed management challenges. This article examines the interstate watershed management framework of the *Chesapeake Bay Program*, which consists of federal, regional, state, and local initiatives.

The following section provides an overview of the Chesapeake Bay Program and identifies the three main common threats to water resources and natural areas: 1) excess nutrients; 2) poor habitat quality and quantity; and 3) development pressures. Next, the paper identifies the three main environmental planning themes that guide planning and management efforts in the Chesapeake Bay: 1) pollution reduction; 2) natural area protection and restoration; and 3) sustainable development. For each of these themes, the strategies used to promote these themes are described and, when permissible, the effectiveness of the strategies is also described. The final section evaluates the Chesapeake Bay Program and identifies strengths and weaknesses of its strategies, as well as the strategies that may be transferable to other watersheds in the United States and around the world.

This examination of water basin management programs implementing comprehensive (i.e., encompassing various pollutant sources), integrated (i.e., across jurisdictional boundaries and policy fields), and innovative management strategies is important for the future advancement in water management. The analysis presented here does not provide a comprehensive blue print for watershed management; conditions vary too much from watershed to watershed for this to be possible, and therefore policies and programs must be tailored to the specific environmental, geographic, hydrologic, economic, and political circumstances of an area. This analysis only attempts to provide an overview of available tools and a general framework for effective water basin management.

Overview of the Chesapeake Bay

The Chesapeake Bay exemplifies a large scale, innovative, high profile program with multi-jurisdictional commitment. The Chesapeake Bay is located along the central east coast of the United States and is the U.S.'s largest estuary with a watershed that covers more than 64,000 square miles and extends over six states—Maryland, Virginia, Pennsylvania, New York, West Virginia, and Delaware—and the District of Columbia. The main body of the bay is roughly 200 miles long, with an irregular shoreline approximately 4,400 miles in length and a surface area exceeding 23,000 square miles (Moreau, 1997). Land use within the Chesapeake basin is characterized as 10 percent developed, 60 percent woodland and nature, and 30 percent agriculture. Furthermore, the bay has

approximately 50 major tributaries; the main tributary basins include the Susquehanna, Potomac, James, Rappahonnock, and York Rivers (NASDA, 1997). In addition, it includes 1,650 local communities consisting of approximately 15.1 million people (CBP, 1999).

In reaction to emerging environmental problems, the Chesapeake Bay Program was formed in 1983 to promote interstate cooperation between Maryland, Pennsylvania, Virginia, and the District of Columbia. The Chesapeake Bay Program has evolved into a nationally renowned regional program that works in conjunction with federal regulations, the Chesapeake Bay Agreement, state programs, and individual local governments.

Threats to water resources and natural areas

The Chesapeake Bay faces a number of threats to water resources and natural areas that present challenges to spatial, environmental and water planning. The three main threats to water resources and nature areas are pollution and eutrophication, poor habitat quality and quantity, and development pressures.

Excess nutrients

The excess of phosphorus and nitrogen nutrients are a critical pollution problem for both the Chesapeake Bay region. Excess nutrients contribute to eutrophication, which is the increase in algae growth, followed by reduced oxygenation, lower water column transparency, and decreased water quality that result in adverse ecological consequences. Excess nutrients often result from the overflow of combined sewage systems, urban runoff, industry, slurry and silage seepage, and runoff from agricultural areas.

Studies of the bay demonstrate that atmospheric deposition and diffuse land discharges are the largest sources of nutrient pollutants affecting water quality (CBP, 1999b; Correll, Jordan, and Weller, 1992). For example, in 1996 diffuse sources contributed 66 percent of the phosphorus load and 57 percent of the nitrogen load to the bay. Whereas, atmospheric deposition contributes to approximately 9 percent of phosphorus and 21 percent of nitrogen entering the bay (CBP, 1999). Important nonpoint sources include runoff from agriculture, construction sites, and urban areas. Therefore, effective land use and environmental planning controls are required to reduce nutrient losses to the environment.

Poor habitat quality and quantity

Poor habitat quality and quantity present another important challenge to planners in the Chesapeake Bay basin. The Chesapeake Bay is facing the loss of important woodlands and wetlands which function as critical habitat and also prevent pollutants and sediment from entering tributaries and reaching the bay. Approximately 59 percent of the bay basin is forested; however, forests are lost at a rate of about 100 acres per day due to suburban development and population growth (Chesapeake Bay, 1998). In addition, the Chesapeake Bay region has more than 1.5 million acres of wetlands; however, population growth and development pressures threaten these wetlands. For example, between 1982 and 1989, 5 acres per year of estuarine wetlands and 3,000 acres per year of freshwater wetlands were lost. Therefore, future protection and restoration of existing and degraded wetlands and forests are essential.

Development pressures

Population growth and development pressure are significant threats to the Chesapeake Bay. Population growth triggers the demand for development which results in the loss of wetlands, forests, and agricultural lands. Unmanaged development also results in increased impervious surfaces and runoff, sprawling development patterns, and inefficient traffic patterns that increase vehicle miles traveled and air pollution (USGS, 1999). The Chesapeake Bay region will experience significant population growth within the next two decades and therefore officials must conscientiously plan for the sustainable development of the area.

The Chesapeake Bay is experiencing rapid population growth that threatens natural areas and water resources. For example, between 1970 and 1997 population within the bay's

watershed grew by 28 percent to 15.1 million and is expected to grow to 18 million by 2020 (CBP, 1988). This population increase is expected to spur the construction of 1.7 million new homes in the region, which under current development patterns will consume more than 636,000 acres of forest and farmland and thus significantly impact the bay's natural resources (CBP, 1999b). Furthermore, vehicle miles traveled has increased 117 percent between 1970 and 1997 and is expected to further increase with intensified development (CBP, 1999b). Therefore, the region must strive to promote efficient growth patterns and transportation systems to reduce land consumption, vehicle miles traveled, and pollution.

Finally, the loss of wetlands, forests, and agricultural lands to sprawl impacts the health of ecosystems (USGS, 1999). Because each land use change generates numerous environmental repercussions, the choices of development type, location, density, construction methods, design and way of conducting day-to-day activities are fundamental in achieving sustainable development (Rogers, 1992). Although incremental land use decisions, like draining a small wetland, encroaching on a stream, and clearing a forest appear to have limited impacts, the cumulative impact of these changes can pose severe environmental consequences on a larger scale. Moreover, since the economy of the Chesapeake Bay region relies heavily upon the health and vitality of the environment, it is very important to plan for sustainable development in order to protect, preserve and restore the water resources and natural areas.

THE CHESAPEAKE BAY PROGRAM

Overview of the management program

Between 1950 and 1970, downward trends in water quality and fisheries attracted national attention to the Chesapeake Bay. In 1965, the U.S. Army Corp of Engineers began a comprehensive study of the bay that focused on navigation, fisheries, flood control, noxious weeds, water pollution, water quality, beach erosion, and recreation (Moreau, 1999). Subsequently, the Chesapeake Bay Program (CBP) was authorized in 1975. Under the CBP, the U.S. Environmental Protection Agency was given the authority to administer a five-year, $27 million study of the bay to examine water quality problems and then recommend a management plan for restoration.

In 1980, the legislatures of Maryland, Pennsylvania, Virginia, and the District of Columbia established the Chesapeake Bay Commission (CBC) to promote interstate cooperation. The CBC established the Chesapeake Executive Council to assess and manage the implementation of coordinated plans, established an implementation committee to coordinate technical matters and plan preparation, and created a liaison office for Bay activities. Responsibilities of the CBC include: 1) identifying concerns requiring interstate action; 2) recommending legislative and administrative actions needed to respond to those concerns; 3) keeping the legislatures properly informed about the region and its resources; 4) representing the common interest of the states in activities involving the federal government; and 5) providing a forum for the resolution of interstate conflicts (Moreau, 1999).

The first Chesapeake Bay Agreement was signed in 1983, initiating a regional partnership to restore the bay (Chesapeake Bay Implementation Committee, 1988). The major participants in the program include the states of Maryland, Pennsylvania and Virginia; the District of Columbia; the Chesapeake Bay Commission (a tri-state governing body); the U.S. Environmental Protection Agency (EPA) (representing the federal government); and citizen participation. In addition, a second Chesapeake Bay Agreement was adopted in 1987 and amended in 1992. This agreement established an overall vision for protecting and restoring the bay, including the main goal of reducing nitrogen and phosphorus loadings by 40 percent by the year 2000. Finally, in June of 2000 the Chesapeake Bay Program signed the new *Chesapeake 2000 Agreement* to guide restoration efforts throughout the next decade.

The Chesapeake Bay Program is considered a national and international model for estuarine restoration and watershed protection. State,

county, and local governments within the Chesapeake Bay watershed have initiated efforts to protect the bay. One of the important aspects of the program is the increased effort by local governments and watershed organizations to reduce pollution, monitor neighborhood water quality, and restore habitat to improve the bay. Local governments also play a vital role in addressing the effects of land use and poor spatial development patterns (e.g., congested roads, costly public services, the decline of open space, destructive land uses and the deterioration of the local environment). Local governments contribute to the success of restoration, and therefore the program continues to focus on their participation as the key to the management of land use in the watershed.

Since its commencement, the Chesapeake Bay Program has created numerous environmental and land use policies to encourage sustainable development and bay restoration. For example, in 1995 the *Local Government Partnership Initiative* was established to coordinate the restoration efforts of 1,650 local governments within the Bay watershed. Also, in 1996 the *Local Government Participation Action Plan* and the *Priorities for Action for Land, Growth and Stewardship in the Chesapeake Bay Region* were adopted to address land use management, growth and development, stream corridor protection, and infrastructure improvements. These programs have identified three basic management themes that local governments can use to protect the bay (Allen and Hall, 1999):

1. *Land management and stewardship* involves reducing resource consumption and costly sprawl development patterns by encouraging the revitalization of existing communities, the protection of agricultural and forested lands, and sustainable development patterns in order to protect important environmental areas and water quality.
2. *Stream corridor protection and restoration* involves coordinating and supporting efforts to protect, enhance, and restore wetland and forest buffers important for filtering sediment and nutrients before reaching the bay.
3. *Infrastructure improvements* involve upgrading, maintaining and inspecting sewage treatment plant facilities, stormwater management infrastructure and septic systems.

The CBP is constantly seeking ways to improve existing programs and deal with emerging challenges. The CBP continues to monitor the effectiveness of policies, research and develop new policies as well as improve existing policies, and convey the program's goals, policies, and restoration status to the citizens of the region.

Strategies for water resource and natural area protection

The following section highlights several important strategies utilized by the Chesapeake Bay Program to promote three main environmental planning themes: 1) nutrient reduction; 2) natural area protection and restoration; and 3) sustainable development.

Nutrient Reduction

To achieve the 40 percent nutrient reduction goal, the Chesapeake Bay Program's overall strategy is to design and implement a comprehensive system of controls and Best Management Practices (BMPs) with consideration of the type of pollutants, their sources, and other environmental, physical, and social conditions that affect water quality. This broad strategy balances regulations with incentive-based programs and delegates implementation to the states to allow flexibility to tailor programs to meet state-specific needs and conditions. Under this framework, the Bay Program focuses on reducing nutrients from both agriculture and urban areas.

Agriculture

Agriculture covers approximately 30 percent of the total surface area of the Chesapeake Bay region and contributes to a significant portion of

the nutrients entering the bay. The nutrients are a result of excess chemical fertilizers, animal manure, sewage sludge used on fields, and animal wastes that run off feedlots and pastures. Some of the main strategies used to reduce nutrients from agriculture sources include the promotion of sustainable farming practices, nutrient management programs, incentive programs, and tributary strategies.

Sustainable farming practices: There are various programs promoting *best management practices* (BMPs) and *best management systems* (BMSs) to resolve water quality problems in the bay watershed and promote sustainable agriculture. BMPs are a wide variety of techniques designed to more efficiently and effectively practice agriculture and to reduce runoff (NASDA, 1997). For example, BMPs include vegetated buffer strips, conservation tillage, streambank fencing, strip cropping, alternative livestock watering systems, and animal waste handling, storage, transportation, and use as fertilizer. Additionally, resource specialists advocate the combination of various BMPs and nutrient management plans for a best management systems approach to more effectively reduce nutrients and improve production. For example, this may include combining conservation tillage practices with grass waterways, strip-cropping, diversions, stream side buffers and a nutrient management plan.

Examples of state programs promoting sustainable agriculture are seen in Maryland and Virginia. Maryland encourages the adoption and implementation of BMPs by offering a range of financial and technical resources to farmers through the Maryland Agricultural Water Quality Cost-Share Program (MACS) (NASDA, 1997). MACS provides farmers with education and up to 87.5 percent of the cost to install a range of eligible BMPs to protect water quality, such as animal waste storage facilities, grade stabilization structures and grassed waterways. In addition, there are more than 850,000 acres managed under certified nutrient management plans and more than 400 individuals certified to provide management services to farmers.

Virginia's Agricultural Stewardship Act (ASA) created a program in which the Department of Agricultural and Consumer Services (DACS) works with farmers and local Soil and Water Conservation Districts (SWCDs) to resolve water quality problems caused by sediment, nutrients, and pesticides from agricultural operations (NASDA, 1997). Under the program, the DAC receives complaints alleging specific agricultural activities are causing water pollution and then investigates and oversees mitigation. The program provides a wide variety of means and BMPs for farmers to correct water quality problems before enforcement action is deemed necessary. For example, a farmer must create a plan with "stewardship measures" and an implementation schedule to prevent water pollution. The plan must include a tract map, affected water feature designation, soil maps, and a statement of pollution problems. This program allows the opportunity for citizens to identify water quality problems and then provides technical, financial, and legal support to farmers to resolve the problems.

Nutrient Management Programs: Because of the high levels of nutrients from agricultural lands, CBP and states have placed significant emphasis on nutrient management programs. The purpose of nutrient management programs is to balance nutrient inputs and outputs by determining the amount of fertilizer required based on factors such as soil condition, crop rotation, and BMPs in use. This maximizes the benefits of fertilizers and minimizes the impacts on water quality. With a goal of placing 3 million acres of farmland under nutrient management programs by 2000, the CBP's nutrient management strategy has been regarded as one of the most successful in the nation (CBP, 1997).

Different states within the Chesapeake Bay region have developed their own nutrient management programs. For example, Pennsylvania created the Nutrient Management Law in 1993 to strengthen manure management standards in order to reduce loads from livestock. Also, in 1998 Maryland passed the Water Quality Improvement Act, which is regarded as the most comprehensive nutrient management law in the country (CBP, October

1997). The Act requires landowners with nutrient application greater than 10 acres, farm operations grossing $2,500 or more annually, or livestock operations with more than eight animal units[1] to prepare nutrient management plans. Maryland provides financial assistance, technical assistance and software packages to aid farmers (MD Department of Agriculture, undated). In addition, Virginia offers state tax credits as incentives to farmers to develop nutrient management plans and to purchase nutrient application equipment (CBP, October 1997).

The number of acres under nutrient management plans is an indicator of the progress of nutrient management programs. Figure 1 illustrates that since program inception in 1986, more than 3 million acres are projected to be under nutrient management by 2000.

Incentive Programs: Sustainable agriculture practices and nutrient management programs often present high upfront costs to farmers. Therefore, there are numerous incentive-based strategies, in particular cost-share programs for agricultural BMPs, to encourage farmers to implement better agricultural practices. Funding for cost-share programs comes from federal agencies as well as state appropriations. State and federal cost-share programs assist farmers with the costs of installation as an incentive for participation, usually in ratios ranging from 80:20, 75:25, or in some cases such as Pennsylvania's streambank fencing program, 100 percent (CBP, October 1997). Figure 2 illustrates the cost share ratios and funding allocations for state cost share programs.

Tributary Strategies: Many strategies were too general to effectively meet the 40 percent reduction goals. Therefore, in 1992 the Chesapeake Executive Council created the framework for tributary strategies in order to address the need for a more area and source specific approach. Tributary strategies are basin-specific nutrient reduction plans designed for each of the ten major tributaries in the bay. They are designed to take into account the watershed's unique physiographic features (e.g., hydrology, soil, and land use), political climate and institutional structures. The strategies were specifically created to deal with the variation in loadings by jurisdiction, and they allow each jurisdiction to establish tailored, comprehensive nutrient reduction strategies that balance regulatory controls with incentive-based programs. Tributary strategies address three primary areas for nutrient reduction: 1) wastewater treatment plants upgrades to incorporate the BNR

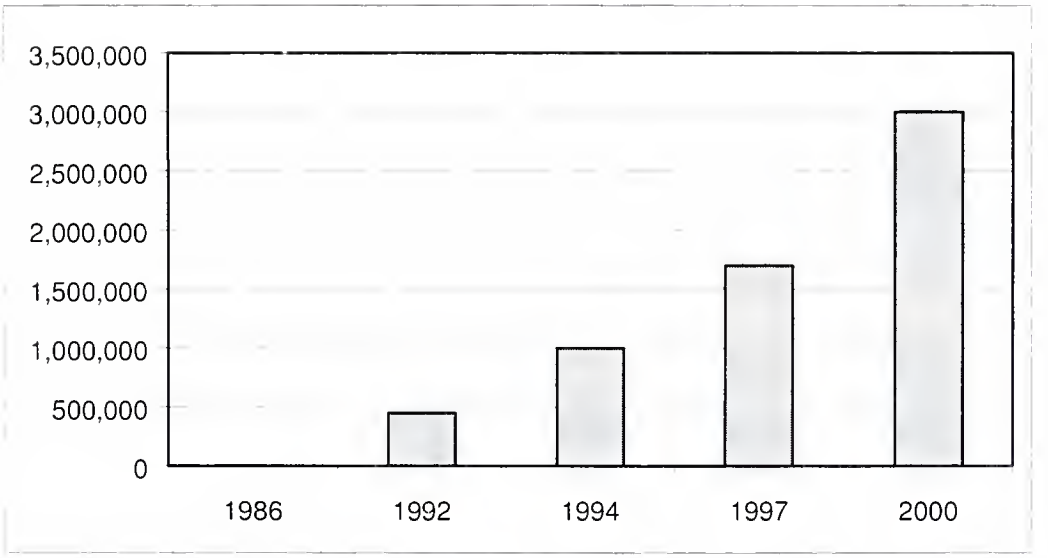

Figure 1. *Acres in Nutrient Management Programs*

State	Cost-Share Ratio	State Funding
Maryland	– 50-87% cost-share ratio – $10,000 cap/practice – $50,000 cap/practice for animal waste storage	– $29.9 million (1983-95)
Pennsylvania	– 80% cost-share ratio – $30,000 cap	– $3 million/year
Virginia	– 75% cost-share ratio – (cap unknown)	– $1 million/year

Figure 2: *Cost-Share Program Allocations (Source: CBP, October 1997b).*

process; 2) agricultural BMPs; and 3) urban storm water BMPs (CBP, 1994).

Another key component of all tributary strategies is public involvement to increase local commitment to the bay's restoration. In particular, there is emphasis on consensus building among major stakeholders, such as farmers and the larger agricultural community, as a way to increase ownership of the plan among constituencies and encourage participation during implementation stages. However, lack of authority and resources and unclear roles and missions present some weaknesses of this approach (CBP, October 1997). Nevertheless, the states continue to support this framework with the belief that local support, locally tailored strategies, and collaboration will significantly enhance the long-term effectiveness and sustainability of watershed based nutrient reductions (CBP, October 1997).

Another important aspect of the tributary strategies program is the introduction of nutrient trading in order to address differences in the cost-effectiveness of nutrient reduction strategies among various tributaries. Because some tributaries, like the Susquehanna Tributary Strategy, fall short of meeting the required 40 percent nutrient reductions, nutrient trading was introduced to compensate for this shortfall by recognizing the increased reductions in other tributaries (CBP, October 1994). Therefore, a 1992 Agreement allows for reallocations of the 40 percent goal to other tributaries outside of the Susquehanna basin (CBP, 1994). All states are considering effluent trading programs but have not yet formally institutionalized the necessary framework.

Urban water

Nutrients from urban areas originate from municipal wastewater treatment plants, sewer overflows and runoff from urban areas (e.g., lawns, roadways, and other developed areas) (NASDA, 1997). Urban best management practices and wastewater treatment plant upgrades are strategies used to decrease nutrients from urban areas. Urban best management practices include erosion and sediment controls on areas under development and stormwater controls in developed areas. These practices are applied by industrial, commercial, and residential facilities to manage lawns, open spaces, and construction sites. Examples include erosion and sediment control,

stormwater management, and septic system maintenance.

Wastewater treatment plant upgrades are another primary control strategy to reduce nutrients. For example, Biological Nutrient Removal (BNR) technology, an advanced nutrient removal system, has been installed in 43 major wastewater treatment plants in the Chesapeake Bay basin. Currently, 48 percent of the flow is treated by BNR and 64 percent of the flow will be treated using BNR after the full implementation of Tributary Strategies. This will lead to a considerable decrease in nutrient loads from municipal wastewater treatment plants.

Effectiveness of nutrient reduction strategies

In 1997, the CBP completed a comprehensive water quality assessment to evaluate progress toward the 40 percent reduction goal. Figure 3 illustrates the reductions in nitrogen and phosphorus between 1985 and 2000. Phosphorus loads declined by 6 million lbs./yr between 1985 and 1998 (mostly due to a ban on phosphates in detergents) and the 40 percent reduction goal was satisfied. However, nitrogen loads declined by 42 million lbs./yr and the 40 percent reduction goal was *not* satisfied. Therefore greater emphasis must be placed on reducing nitrogen loads.

Natural area protection and restoration

The Chesapeake Bay relies on coordinated public and private actions to protect forests and wetlands in the bay's watershed. Strategies used to protect and restore natural areas are the Riparian Forest Buffer Initiative, preservation programs, and the Wetlands Initiative.

Riparian Forest Buffers Initiative

Protecting riparian forest buffers through acquisition, easements, and development regulations is important for water resource and natural area protection. Nearly 50 percent of the bay's riparian[2] forests have been converted to other land uses or degraded. It is important to protect and restore riparian forest buffers because they filter pollutants such as nutrients, sediment, and pesticides in surface and groundwater, and reduce downstream impacts for floods (CBP, March 1999). Nutrient and sediment reductions of 30 to 90 percent can occur when runoff and groundwater pass through riparian forest buffers. In addition, riparian buffers are recognized as an effective control measure to maintain streambank stability, enhance and restore stream habitat, provide corridors for wildlife, and provide cooler water temperatures, leaf litter, and cover for aquatic species.

With over 111,000 miles of perennial and intermittent streams in the Chesapeake Bay watershed, protecting riparian forest buffers is a challenge. In 1996, a Riparian Forest Buffers Initiative was adopted to increase riparian buffers[3] on 2,010 miles of stream and shoreline in the watershed by the year 2010 (CBP, 1999a). In order to reach this goal, Maryland and Pennsylvania will restore 600 miles, Virginia will restore 610 miles, and D.C. and federal lands

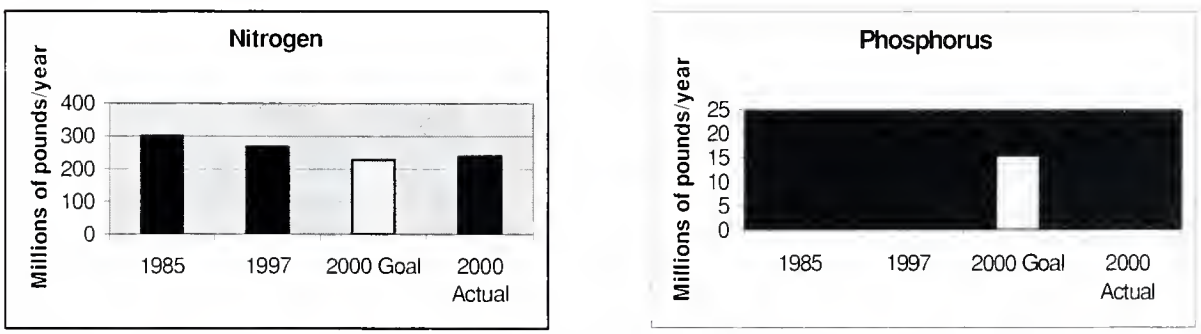

Figure 3: *Effectiveness of Nutrient Reduction Strategies (Source: Chesapeake Bay Program, 1999).*

will restore 200 miles of riparian forest buffers. As part of this initiative, the Chesapeake Bay Program and signatory jurisdictions revise or adopt local zoning and subdivision ordinances, comprehensive land use plans, and regional or watershed stormwater management plans to restore riparian buffers. Additional restoration efforts involve small grant programs, federal-state partnerships supporting Conservation Reserve Enhancement Programs, cost-share programs, tax breaks, easements, and acquisition. The results of restoration efforts are promising. Between 1996 and 2000, approximately 711 miles of riparian forest buffers were restored, which is 35 percent of the 2010 restoration goal.

Preservation programs

The Chesapeake Bay Program seeks to permanently preserve critical environmental areas and relies on public-private partnerships to achieve this goal. The 2000 Chesapeake Bay Agreement guides the next decade of restoration in the Chesapeake Bay watershed. This new agreement has committed members to "...permanently preserve from development 20 percent of the land area in the watershed by 2010" (CBP, December 2000). This goal translates into permanently preserving 7,783,856 acres from development. The CBP plans to permanently protect this land through perpetual conservation or open space easement or fee ownership, held by a federal, state, or local government or non-profit organization.

It is estimated that 6,688,757 acres are currently preserved by all signatory jurisdictions. Of this total amount, approximately 2,116,305 acres are owned by the federal government, 4,209,227 acres are owned or eased by the state governments, 282,291 acres are owned by the local government, and 80,934 acres are owned or eased by nonprofit or other private sources. Subtracting from the acres of land already preserved, there are an additional 1,095,099 acres remaining to preserve in order to meet the 2010 goal.

The Wetlands Initiative

Nearly 1.5 million acres of wetlands occupy the Chesapeake Bay watershed, but increasing population and development pressures are degrading and destroying both tidal and nontidal wetlands in all of the Chesapeake Bay states (CBP, undated a). The Chesapeake Bay Program has recognized the important role that wetlands play in the overall health of the bay and its living resources and has committed itself to protecting and restoring wetlands. In 1988, the Chesapeake Bay Program developed the Wetlands Policy Implementation Plan which established a "no net loss" goal for the watershed. The plan called for fostering the protection of wetlands through four strategies: 1) the inventory and mapping of wetlands; 2) the protection of existing wetlands; 3) the rehabilitation and restoration of degraded wetlands; and 4) education and research. In addition, in 1997 the CBP developed strategies to identify and track wetlands in the Chesapeake Bay watershed to achieve a net gain in wetlands acreage and to assist local governments and watershed groups in wetland management.

Maryland, Virginia, and Pennsylvania have tidal and nontidal wetlands programs to help develop policies and regulations toward wetland protection. In addition, the states have taken steps to protect wetlands beyond the regulatory programs. For example, in 1996 Maryland established a 60,000-acre wetlands net-gain goal, and Pennsylvania has stricter mitigation requirements under their regulatory wetlands program. In order to assist the states with wetlands protection, the 1997 Chesapeake Executive Council adopted an additional wetlands policy designed to speed the restoration and protection of wetlands in the Chesapeake Bay basin. Under Directive 97-2, Wetlands Protection and Restoration Goals, the CBP focuses efforts for achieving no-net-loss of wetlands and to move toward a net gain in the Chesapeake Bay watershed. Under Directive 97-2, the CBP and its partners are committed to complete and publish wetlands status-and-trends reports every five years, to develop state strategies for achieving net gains, to publish a community-based approach to wetlands

preservation and restoration, and to develop quantifiable wetland restoration goals. Despite these efforts to protect and restore wetlands, however, wetland loss still continues.

Effectiveness of natural area protection and restoration

With more than 90,000 acres (150 square miles) of open land consumed annually by growth in the Chesapeake Bay States, the protection and restoration of natural areas is increasingly important as well as challenging. Public and private institutions have united to protect and restore riparian forest buffers, preserve important environmental areas, and stop wetland degradation. The results of current efforts are promising, but continued future support is required. In order to meet its goals, the program must restore 1,299 acres of riparian forests, preserve over 1 million more acres of land, and continue to strive for a net gain in wetlands. This will require significant cooperation and commitment from national, state, and local governments and nonprofits.

Sustainable Development

To promote sustainable development, the Chesapeake Bay primarily relies on voluntary county and local governmental actions, like development management tools, to control land-use planning, water and sewer planning, construction, and other growth-related management processes (Allen and Hall, 1999). Bay restoration and protection programs concentrate on coordinating local initiatives involving land use management, stream corridor protection, and infrastructure improvements. The following highlights some of the important development and land use management strategies utilized by state, county, and local governments within the Chesapeake Bay watershed. Tools described and assessed include critical area regulations, urban growth boundaries, infill/community redevelopment, transfer of development rights, subdivision requirements and cluster zoning, and potential funding strategies for water resource and natural area protection.

State critical area regulations

Both Virginia and Maryland utilize critical area regulations to protect important lands adjacent to the bay. Critical areas are typically identified on a state and regional basis because natural areas cross political jurisdictions and therefore require the cooperation of multiple jurisdictions. Critical area regulations provide multi-jurisdictional commitment and long range planning for significant natural resources. Programs require a broad range of skills and resources for planning, legal justification, and financing, in addition to incorporating various development management tools to balance development and conservation.

For example, Maryland adopted the Chesapeake Bay Critical Area Protection Law in 1984, declaring that the state has a critical and substantial interest in fostering more sensitive development activity along the Chesapeake Bay shoreline in order to minimize damage to water quality and natural habitats (Malone, 1990; Godschalk, 1987). The Act defines the critical area as "lands beneath the Bay and all uplands within 1,000 feet of tidal water or tidal wetlands" and classifies existing development within the critical areas as:

1. *intensely developed areas*—existing developed areas where new growth should occur and improvements to water quality and water conservation are stressed;
2. *limited developed areas*—development is allowed as long as it does not change the established density and prevailing land use and it must improve water quality and conserve existing natural habitat; and
3. *resource conservation areas*—development cannot exceed an overall density of one development unit (du)/acre.

In addition, local governments are required to develop local zoning and development plans that include limiting commercial and industrial development, reducing impervious surfaces,

protecting shore erosion, and describing landscaping requirements.

Maryland's Critical Area Protection Law has been considered to be one of the most extensive and innovative coastal area protection programs in the country; however, there are some criticisms of the regulation. For example, some criticize that the standard, uniform specifications are over-simplistic in that they disregard the differences between shore locations and fail to recognize the potential use of performance standards to mitigate environmental impacts. In addition, the restrictions limiting residential development on land abutting the bay has affected housing prices. Critical area restrictions increase housing prices because they limit the supply of land available for housing construction and increase the value of the shoreline development as an amenity, which is capitalized into the value of land and housing prices (Parsons, 1992). A study of housing price increases resulting from Maryland's critical area restrictions estimated that housing prices for areas with water frontage increased between 46 and 62 percent, prices for housing without frontage increased between 14 and 27 percent, and prices for housing near but not in the critical area increased between 13 and 21 percent (Parsons, 1992).

Urban growth boundaries

An urban growth boundary is a planning tool that guides future development by delineating an arbitrary line around a geo-political region in order to distinguish areas appropriate for urban expansion from areas appropriate for agriculture, rural, and resource protection (Frankel, 2000). The boundary should also coordinate with a strategy that provides the necessary urban services to ensure efficient and timely development. Urban growth boundaries not only serve the local community by encouraging more cost-efficient development, they also can improve the health of the bay by promoting compact urban development and preserving important natural areas from development (CBP, 1997a). For example, urban growth boundaries can limit the number of vehicle miles traveled, protect important environmental areas, and reduce impervious surfaces.

An example of a community using urban growth boundaries as a development management tool within the Chesapeake Bay watershed is the Isle of Wight County, VA. The Isle of Wight County created Development Service Districts that coincide with major transportation corridors and future sewer service expansion plans in order to protect important rural lands from development (CBP, 1997a). Within the districts, the county assumes the responsibility of providing infrastructure, therefore decreasing development costs and encouraging development within the districts. In addition, the county revised land use management ordinances to establish performance standards for landscaping, control of access, lot coverage, and buffering in order to better manage development and protect sensitive environmental and agricultural areas.

Infill/community redevelopment

Promoting infill development allows a community to revitalize existing urban areas, provide adequate and affordable housing, utilize existing infrastructure and reduce the consumption of rural and environmentally sensitive lands. Infill development benefits the region by reducing the number of vehicle miles traveled, reducing the need for septic systems in rural areas which contribute to excess nutrients within the bay, and encouraging the clean up of contaminated sites for future use which reduce the amount of toxic pollutants entering the bay.

An example of a community within the Chesapeake Bay that actively promotes infill development is Lititz Borough, PA (CBP, 1997a). Lititz Borough is located in Lancaster County and has policies to sustain a vibrant downtown center, preserve the town's historic district, and preserve rural lands. In order to promote infill development in downtown, Lititz Borough has a seven-year tax abatement program for commercial and industrial businesses that locate within the downtown. In addition, the town also utilizes an urban growth boundary to promote growth in designated areas and to discourage sprawl outside of the town's limits. Lititz Borough is an example of how a community

coordinates different development management techniques to encourage economic development, compact urban form, and environmental sustainability. The utilization of different development management techniques to promote infill and prevent pollution contributed to Lititz Borough's designation as a Gold Chesapeake Bay Partner Community for efforts to protect its land, rivers, and the bay.

Transfer of development rights (TDR)

The Transfer of Development Rights (TDR) is a tool that allows for the transfer of development rights of one parcel in exchange for the right to develop another parcel more intensely (Smith, 2000). TDR serves as a market-driven, incentive-based development management tool that provides compensation to a landowner without the need for expensive public acquisition (CBP, 1997a). Benefits to the bay include permanently preserving environmentally sensitive areas, forests, and agricultural lands that serve as natural pollution buffers and filtration areas for water quality. In addition, it minimizes the number of septic systems, amount of impervious surface, and the number of vehicle miles traveled.

Montgomery County, MD maintains a careful land management program with more acres preserved under legal protection than any other urban county in the nation. In 1997, over 93,000 acres, nearly one-third of the county, was preserved under legal protection (Allen and Hall, 1999). The County designated 90,000 acres within the sending areas, and has downzoned the area from 1 du/ 5 acres to 1 du/ 25 acres and has allowed one credit per five acres to sending area owners (Smith, 2000). In addition, the county has designated receiving areas where public facilities and public services can support higher density development. The program has been relatively successful; approximately 6,629 development rights from over 400 properties have been severed by easements for a land area of 43,993 acres. Of these, only 5,123 have been transferred to receiving zones. The success of Montgomery County's program is attributed to a land market that promotes TDR sales from the sending areas to the receiving areas, the appropriate determination of the value of TDR's to buyers and sellers, and a clear program that has been properly marketed to landowners, developers, realtors, bankers and attorneys (CBP, 1997a). However, one drawback of the TDR program is that from a regional prospective, Montgomery County cannot prevent development from areas outside its borders.

Subdivision requirements and zoning

Subdivision regulations can play an important role in the protection of important natural areas. For example, cluster zoning allows for the protection of rural character and minimizes the impacts on resource lands by focusing growth into smaller areas of a parcel and preserving the remainder as open space or farmland. Clustering can improve stormwater management by allowing stormwater to be channeled and detained in detention ponds located within the open space. In addition, specified vegetated buffer requirements within subdivision regulations are important to filter sediments and pollutants, reduce flooding, and protect water quality within the watershed.

Howard County, MD, located between Washington D.C. and Baltimore MD, has adopted subdivision controls and cluster zoning to mitigate the effects of rapid growth that threaten rural areas. For example, Howard County's Subdivision and Land Development Regulations require wetlands to be placed in open space when it is created, a buffer of 25 feet around nontidal wetlands, a buffer of 75 feet along perennial streams in residential zoning districts, and a buffer of 50 feet along intermittent streams and along perennial streams in nonresidential zoning districts (Howard County, 1999). Furthermore, because the county's three acre lot minimum was not adequate to handle growth pressure, in 1992 the county adopted three rural cluster districts with specific guidelines to aid developers in subdivision design (CBP, 1996):

1. *Rural Conservation* (RC) allocates priority to agricultural uses and permits residential use at a density of 1 dwelling unit per 4.25 acres with mandatory clustering on parcels greater than 20

acres:

2. *Rural Residential* (RR) applies to areas where the most extensive subdivision has already taken place and is intended to accommodate most of the demand for rural residential development as infill: and

3. *Density Exchange Option* (DEO) is an overlay district that covers all lands within the RC and RR districts. Density may be exchanged between qualified sending and receiving areas. The intent is to give farmers considerable flexibility in transferring density away from the best farms to those locations that have the least long-term viability for agriculture.

Howard County's subdivision regulations and cluster zoning has been relatively successful, and there has been a strong demand for clustered lot subdivisions. In addition, an assessment of Howard County's General Plan cites rural clustering and density exchange as devices to help achieve its goal of 30,000 acres under protection from future development (Howard County, 1999). However, the county did not achieve greater use of shared septic systems to create tighter rural clusters because costs and the agency approval process discouraged implementation.

Potential funding strategies for protecting water resources and natural areas

There are various funding strategies used in the Chesapeake Bay region to support sustainable development. First, a special assessment district can be used to protect or improve a special geographic feature. A special assessment district is an independent government entity formed to finance governmental services for a specific geographic area, such as a stream, small watershed district, or natural resource management district. Residents of the special district pay taxes to finance specific improvements that will benefit them or resolve a community problem, like excessive runoff in the district. For example, residents interested in reclaiming a wetland or improving a waterway can use a special assessment district to manage and finance the project.

Second, a stormwater management utility is an enterprise that can charge landowners a fee based on parcel size and the degree of development. The revenue from this fee can be dedicated to stormwater management activities, such as retrofitting existing systems or providing sediment and erosion control. Third, wetland or forest banking can be used to replace a wetland or forest destroyed by development. Mitigation banks facilitate the administration of a system where appropriate areas for wetlands or forests are matched with developers in need of satisfying off-site mitigation requirements.

Fourth, local governments can utilize a State Revolving Fund where the state provides funds to finance both public and private sector projects that enhance or protect water quality. Projects may include septic system repair or replacement, erosion control, upgrading wastewater treatment facilities, or the construction of animal waste storage facilities. Finally, an endowment fund from a public or private organization can be used for a variety of projects, such as wetlands and habitat creation/restoration, tree planting and streambank stabilization.

Effectiveness of development strategies

The effects of development management are difficult to determine empirically; however, recent modeling efforts indicate the potential effects of different development scenarios. An analysis presented in *Integrating Build-Out Analysis and Water Quality Modeling to Predict the Environmental Impacts of Alternative Development Scenarios* (1998) indicates the potential results from different buildouts within Maryland's Patuxent River watershed. The Maryland Office of Planning (MDOP) modeled land and water resource impacts of three different development alternatives (CBP, March 1998):

1. *2010 Base Zoning* ("worst case scenario"), portraying new development according to current zoning but without the influence of other existing county

subdivision and environmental ordinances and without BMPs for nutrient management;

2. *2010 Current Programs*, portraying new development under current zoning, subdivision, and environmental regulations, as well as implementation of agricultural nonpoint source pollution control; and

3. *2010 Directed Growth*, portraying enhanced levels of growth management, land conservation, and pollution control practices included in Maryland's Tributary Strategies, such as forest conservation, stream buffer protection, rural clustering, increased development potential in growth areas, transfer of development rights, extending sewer service in designated growth areas, protective agricultural zoning, and the purchase of development rights.

The results of modeling the three scenarios suggest that implementation of both growth management and pollution control options are essential in maintaining nutrient load caps beyond the year 2000. In the year 2010, modeling results suggest that pollution levels will be much lower if growth and new development is well directed. In addition, growth management applied in conjunction with other management tools, such as BMPs, will be one of the most important factors determining future pollution levels. For example, MDOP estimates that in the year 2010, nitrogen pollutant loads to the Patuxent River watershed could be about 1,141,000 pounds lower if "Directed Growth," "Resource Protection," and BMP options were used to manage growth. In addition, by the year 2010, stream quality would degrade in nearly half of the Patuxent watershed under the *Current Programs*, while under the *Directed Growth* scenario stream quality would limit degradation to about one quarter of the watershed. The modeling results suggest the importance for state, county, and local governments to continue to pursue sustainable development strategies.

EVALUATION OF THE CHESAPEAKE BAY PROGRAM

The water resource and natural area management approach of the Chesapeake Bay exemplifies a comprehensive, integrated, and innovative management program that can serve as a model for the development of future programs. The following section evaluates the program to protect water resources and natural areas. It identifies the strengths and weaknesses of the Chesapeake Bay Program and some of the strategies that can be applied more broadly in this country and abroad.

Although millions of dollars have been spent on bay restoration programs since the Program originated in 1983, measuring the effectiveness of any program is difficult because of the indistinct link between programs and improvements to water quality and natural areas. However, a general assessment of the strategies utilized by the Chesapeake Bay Program demonstrates a number of significant strengths. Overall, the Chesapeake Bay Program displays good interstate and intrastate cooperation and community involvement. The program goes to great lengths to promote community outreach and provides many opportunities for citizen involvement. In addition, the program is improving its monitoring systems and includes an integrated goals and indicators system that clearly illustrates the status of restoration efforts.

The Chesapeake Bay Program has also created innovative nutrient reduction strategies. For instance, Tributaries Strategies are a flexible and area-specific approach to nutrient reduction. In addition, the Chesapeake Bay has advanced cost-share programs that encourage farmers to implement BMPs. In addition, governments and non-profits within the Bay have successfully collaborated to protect millions of acres of natural areas and hundreds of miles of riparian forest buffers. Furthermore, the Chesapeake Bay Program is proactively coordinating the support of the 1,650 communities within the Bay for a bottom-up approach to development management.

However, the Chesapeake Bay still faces several issues that will require the additional attention from policy makers, local governments, and community members. For example, the nutrient reduction strategies have not effectively reduced nitrogen loads. More innovative strategies must be developed (such as market-oriented nutrient trading programs) and more money should be allocated to cost share programs to help farmers implement BMPs. Moreover, additional efforts are needed to halt wetland degradation in order to achieve the goal of a no net loss of wetlands. The Chesapeake Bay could learn from more effective natural area protection programs and nutrient reduction strategies already implemented in places like the Netherlands. Finally, since many of the sustainable development strategies are dependent on market and private developers, there is great uncertainty to whether development management techniques will effectively influence private developers.

CONCLUSION

Lastly, an examination of water basin management programs that implement a holistic approach that encompass comprehensive, integrated, and innovative management strategies is important for promoting sustainable development. The Chesapeake Bay case study illustrates the complexity of water and nature management and the creation of innovative management strategies. It displays various approaches to promote nutrient reduction, natural area protection and restoration, and sustainable development. For example, noteworthy strategies that may serve as models for future management plans include the Chesapeake Bay's Tributary Strategies, cost-share programs that alleviate costs for farmers implementing best management practices, the Riparian Forest Buffers Initiative, and various development management techniques designed to promote efficient development. This analysis does not serve as a comprehensive blueprint for management; policies and programs must be tailored to the specific environmental, geographic, hydrologic, economic, and political circumstances of an area. However, many of these strategies may be applied to management systems in other regions and countries to improve water resources and natural area protection.

[1] 1,000 pounds live weight = one animal unit.

[2] Riparian areas are lands adjacent to a body of water, such as streams, rivers, marsh, and shoreline.

[3] According to the Initiative, a riparian forest buffer is defined as "a conservation width of at least 100 feet on each side" (CBP, March 1999).

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